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Cottonseed Meal for Pigs

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COTTONSEED MEAL FOR PIGS

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Cottonseed meal is produced in greater abundance than any other protein concentrate. The average annual production of cottonseed cake and meal for the 5 crop years from October 1, 1927, to September 30, 1932, inclusive, was 2,233,479 tons, or over 3.7 times as much as that of linseed cake and meal for the same period. Pound for pound of protein contained, cottonseed meal is often one of the cheapest supplemental feeds available. When used as the only protein concentrate in dry-lot feeding, with corn or other grain, and when fed in sufficient quantities to balance the ration, some cottonseed meals prove injurious to growing and fattening pigs.

The following statements are taken from the eighteenth (1923) edition of Henry and Morrison's *Feeds and Feeding*: "Cottonseed is most poisonous to swine. .....No uniformly successful method of feeding cottonseed meal to swine has yet been found. Steers closely confined and heavily fed on cottonseed meal often are affected by the poison after a period of about 100 days. They have a staggering gait, some become blind, and death frequently ends their distress. Young calves are especially susceptible to the poison."

Differences of opinion exist as to the cause or causes of the harmful effects sometimes resulting when cottonseed meal is fed. An excess of acid-forming over base-forming elements (52), the oil content of the meal, the fiber or lint in it, unsaturated fatty acids, decomposition products, nitrogenous materials, and certain compounds of phosphorus (33) have been suggested at one time or another as possible causes. Other investigators (5, 24, 25, 33, 42, 47, 51) have regarded the trouble as due to the use of rations which were deficient in certain vitamins or minerals.

In 1915 Withers and Carruth (54) reported that the toxicity of cottonseed meal was due to a compound called *gossypol.* Gossypol can be extracted from cottonseed with certain solvents such as ether or acetone. They and others (11, 48, 55) have definitely demonstrated that purified gossypol has a poisonous effect, similar to that of cottonseed, when it is fed to rabbits, rats, guinea pigs, and swine.

Gallup (16) reported in 1926 that "studies to determine the cause of the deleterious effect arising from the feeding of cottonseed meal to certain types of livestock and other animals, have been carried out to such an extent and such evidence brought to light on the subject, that we feel quite safe in assuming the trouble to lie in the toxic properties of a substance isolated from cottonseed and called 'gossypol'." He mentions that such an assumption is not without criticism and that it does not necessarily follow that whenever injurious effects are encountered with the use of cottonseed meal as a feed, the only cause is due to gossypol. In his opinion, however, gossypol is the chief cause of the injury, when balanced (that is, adequate) rations are fed. He states that cottonseed meal contains a high percentage of protein which is of excellent quality and quite digestible.

According to Huffman (25) "the protein of cottonseed meal is of high quality, since it contains all of the amino acids in the proper proportions for growth and milk production." Other investigators (6, 32, 37, 38, 39, 42) have likewise reported a high nutritive value for the proteins of cottonseed or cottonseed meal.

The common procedure in the manufacture of cottonseed meal is to clean the seeds, remove more or less of the lint covering them, cut the hulls and separate them from the kernels, and then crush the kernels, cook them, and expel the oil with a hydraulic press. Some mills are now using a continuous screw type press, known as an expeller. The meal is made by grinding the pressed cake. Two processes of cooking are employed. In one, the crushed kernels are cooked in large steam-jacketed kettles equipped with agitators. Sometimes additional steam is applied directly. The other is a continuous process in which the crushed kernels are cooked in a steam-jacketed drum provided with an apparatus for stirring the kernels as they pass through.

Clark (9) states that there is considerable variation in the time and temperature of the processing, regardless of which method of cooking is employed, but that generally from 25 minutes to 2 hours constitute the time of treatment and that from 20 to 40 pounds of steam pressure are maintained in the jackets of the drums or kettles.

If ether is used to extract the gossypol from cottonseed meal made in the usual manner, much less gossypol than that present in the untreated seed is obtained. Yet, the oil that has been removed contains little or no gossypol.

Concurrently with the decrease in the extracted gossypol, the toxicity of the meal, as compared with that of the seed from which it is made, is apparently reduced, at least for some classes of animals. One explanation of the reduction in toxicity was that there was a change in the gossypol molecule during the cooking and pressing process used in the manufacture of the meal. Withers and Carruth (55) believed the change was mainly one of oxidation. Carruth called the changed and supposedly oxidized substance D gossypol. Sherwood (49) later suggested that the change from gossypol to D gossypol was one of hydrolysis.

More recently Clark (9) has presented evidence indicating that the gossypol molecule undergoes no chemical alteration such as oxidation or hydrolysis. His theory of what happens to the gossypol in the manufacture of the meal is as follows: "During the heating and pressing to which the seeds are subjected, the resin glands containing the gossypol are disrupted and possibly much of the gossypol is dissolved in the oil present. It thus comes in intimate contact with the proteins of the seeds and in this condition, favored by heat and pressure, probably condenses with free amino groups of the protein molecules, as it does with many primary amines, forming substances similar in type to dianiline gossypol. The material is thus *bound*, rendering it insoluble, and, as far as is known, physiologically inert. The work of Jones and Waterman (29), in which they found that peptic and tryptic digestion of casein and cottonseed globulin was reduced 15 per cent when treated with 1 per cent gossypol, lends support to this idea."

In the 1930 Year Book of the United States Department of Agriculture the following statement is made by the secretary: "It has been shown that the supposed danger of gossypol poisoning from the use of cottonseed cake meal as a feed for livestock does not exist."

In the cooperative biological investigations carried on by Clark, Nelson, and Jones, the growth rates of rats fed diets containing high levels, 40 per cent, of cottonseed meal were accelerated by the inclusion of casein in the diet. The growth rates were also influenced by the composition of the added mineral supplement. In Clark's report (10) of the findings of these investigations,

the belief is expressed that, if cottonseed meal were used as a supplement to other feeds, the proteins of the other feeds would correct the deficiency of the cottonseed meal proteins and thus result in an excellent ration for livestock.

Basing his conclusion on the assumption that the so-called D gossypol (the less soluble form) was not toxic, Sherwood (49) concluded that all but five out of 40 samples of cottonseed meal tested were so low in gossypol that it could not produce injury in albino rats, even when the meal constituted 50 per cent of a well balanced diet.

Gallup (17), however, fed ether-extracted meals to rats at 35 and 45 per cent levels and found that "ether extraction of the meal, which removes some of the gossypol in a proven toxic form, aided but little in preventing injurious effects, indicating that the insoluble form of gossypol, which occurs in the meal in relatively large amounts, is also toxic." Withers and Carruth (55) reported that, although the modified form, or so-called D gossypol, had little effect on rats, it was toxic to rabbits and swine.

These citations emphasize the diversity of opinion existing as to the cause or causes of the harmful effects sometimes resulting when cottonseed meal is fed. One group of workers believes that the proteins of cottonseed meal are of high quality and that the trouble is due to feeding the meal in rations which are deficient in vitamins or minerals. Another group regards the inadequacy of the proteins as the causative factor and believes the gossypol in the seed is changed to a bound, insoluble, or harmless form during the process of manufacturing the meal. Still another group believes that gossypol is the chief cause of the trouble.

Experiments with high-protein feeds of plant origin (43, 44, 46[1]) for supplementing corn for pigs in dry lot have demonstrated that feeds of this character, such as soybean oilmeal and linseed meal, like the grains and many of their by-products, are deficient in minerals and in vitamin D. In addition to these deficiencies, white corn is also deficient in vitamin A (27, 36, 41). Since cottonseed meal is somewhat similar in composition to linseed and soybean oilmeal, rations of it and corn would likewise be expected to be deficient in minerals and vitamin D and in vitamin A as well, if white corn were fed. Doubtless, the problem was complicated, especially in some of the earlier experiments, by the feeding of rations which were deficient in one or more of these respects. Theoretically at least, as has been done with similar feeds, it should not be difficult to preclude vitamin and mineral deficiencies if vitamin-rich substances and a suitable mineral mixture are included in the ration.

Another factor which has probably been responsible for a part of the confusion as to the cause or causes of the harmful effects sometimes occurring when rations containing cottonseed meal are fed is the fact that different species of animals vary in their susceptibility to the injury.

There is a growing body of evidence to indicate that gossypol is only slightly, if at all, toxic to cattle.

The findings of investigations carried on at the Michigan Experiment Station (26, 35, 40) are reported to be in accord with the theory that cottonseed meal injury in cattle is not due to a toxic principle in the meal but to the deficiency of a factor or factors carried by good quality hay. Cottonseed meal produced no injurious effects when it was heavily fed, for three successive generations, in a ration which was balanced from the standpoint of the various dietary factors. At a 20 per cent level, cottonseed meal from the same supply

[1]Also unpublished experiments (1920, 1921, and 1923) with linseed meal, by the author.

was injurious to growing pigs. Blindness and stiffness of gait, or symptoms similar to those of cottonseed meal injury, on the other hand, were produced in two bull calves fed a ration of corn gluten meal, corn distiller's grain, oats, yellow corn, and wheat straw.

Heifers receiving raw cottonseed as 25 per cent of the dry matter of their feed showed no symptoms of injury. When raw cottonseed from the same source was fed at a 12 per cent level in an adequate ration, it caused the death of two pigs after 60 and 80 days, respectively.

The results of investigations at the North Carolina Experiment Station (24) agree in indicating that cottonseed meal injury in cattle is a deficiency disease. Deaths were caused by feeding a poor quality of roughage with linseed, peanut, and soybean oilmeal, as well as with cottonseed meal.

Bechdel (5), of the Pennsylvania Station, fed from 4.5 to 6 pounds of cottonseed meal daily a head, along with pearled hominy and dried beet pulp, to eight yearling heifers. Two were given cod-liver oil after the first 2 months and remained normal during a 10-month feeding period. Shortly after 6 months the others began displaying symptoms of malnutrition, such as a loss of appetite, scouring, a staggering gait, partial blindness, oily exudations on the skin, slight oedema about the legs, neck, and brisket, and a failure to conceive. Four of the six were brought to normal by adding cod-liver oil to their ration. Another was fed good quality alfalfa hay and promptly returned to a normal physical condition.

In some of the trials with beef cattle (6, 21), in which the two supplements have been compared, cottonseed meal has given as good results as linseed meal. In others (11, 21), particularly those in which liberal amounts of supplement were fed to young animals for comparatively long periods of time, cottonseed meal has failed to show up as favorably as linseed meal.

Gerlaugh (21) compared cottonseed meal and linseed meal as supplements to corn, corn silage, and mixed hay for fattening heifer calves. When the supplements were fed at the rate of one pound daily a head, the two feeds produced gains at the same rate and with less than a pound's difference in the concentrates, corn, and supplement required per unit of gain. When the supplements were fed at the rate of 2 pounds daily a head, the calves getting cottonseed meal made a favorable showing during the early part of the 17-week feeding period. For the entire time, however, they gained 7 per cent less rapidly and required 8 per cent more concentrates per unit of gain than those getting linseed meal. Perhaps, under certain conditions, cottonseed meal may sometimes exert a slightly retarding influence and yet produce no marked, injurious effect.

Gray and Ridgeway (22), of the Alabama Experiment Station, found that cottonseed meal, which was fed to ewes without ill effects, caused the death of several hogs in the swine experiments. In a trial by Dowell and Menaul (12) a single mature sheep which was kept in a dry lot for 3 months and fed alfalfa and prairie hay showed no ill effects from receiving one pound of cottonseed meal daily.

Albino rats are capable of eating rations containing rather large amounts of cottonseed meal or even of raw cottonseed without showing symptoms of poisoning. Pigs, on the other hand, are particularly susceptible to its harmful effect. Rabbits and guinea pigs (19, 34) are likewise very susceptible to the toxic action of gossypol; hence, if used for laboratory investigations, the findings obtained with them in this respect would probably more nearly correspond with what could be expected in swine feeding than if rats were used.

Some conception of the relative susceptibility of pigs and rats may be gained from the results of tests in which cottonseed meal and raw, crushed cottonseed were fed to both classes of animals.

Two pigs were fed a ration of yellow corn, 78.5; raw, crushed cottonseed, 10; tankage, 6; ground alfalfa, 3; and minerals, 2.5. Two others were fed a mixture of corn, 81.5; raw, crushed cottonseed, 5; tankage, 8; ground alfalfa, 3; and minerals, 2.5. The tankage was added in different amounts to keep the protein content of the two rations the same. It was not known at the time that tankage or other protein feeds exert a protective influence against the injurious effect of cottonseed meal.

One pig died 58 days and the other 69 days after being placed on the ration containing 10 per cent of raw cottonseed. A pig getting the raw cottonseed at the 5 per cent level died after being on feed 116 days, but its death was thought to be an indirect consequence of hernia. The other pig on the same ration made a gain of 149 pounds in 140 days, and the experiment was then discontinued. It appeared healthy at the close of the test.

Hunt (28) fed raw cottonseed from the same supply to rats at 20, 30, and 40 per cent levels for a period of 84 days. No deaths resulted except among the rats receiving the feed mixtures containing 40 per cent of cottonseed.

In his tests with cottonseed meal, Hunt (28) concluded that "84 per cent was about the maximum amount of cottonseed meal that could be fed to a rat and at the same time include the proper supplement which was necessary to make a complete diet." This is reiterated in the same report by the statement that 84 per cent of cottonseed meal can be fed to rats without ill effects on growth. Hale (23) states "that for best results, as much as 12 per cent of cottonseed meal should not be included in the ration for hogs, but that it is entirely safe to include as much as 9 per cent of cottonseed meal in the ration for hogs, even when the ration is to be fed for an indefinite period of time." Our experiments with swine likewise indicate that, when it is used as the only protein concentrate, from 10 to 12 per cent of cottonseed meal is as much as can ordinarily be included in the ration without danger of it proving injurious to the animals. Such investigations indicate that, with the meal as well as with the raw seed, pigs are several (from five to seven) times as susceptible as rats.

EXPERIMENT 1

In 1928 a series of experiments to determine the possibilities of cottonseed meal as a protein supplement for growing and fattening pigs was undertaken. In the first trial cottonseed meal was fed with yellow corn, ground alfalfa, and minerals to five lots of pigs. The rations for Lots 1 to 4, inclusive, differed only in their mineral content. One was fed a mixture of salt, limestone, bone meal, and potassium iodide. A mixture including iron oxide, iron citrate, and a combination of iron oxide and copper sulfate for Lots 2, 3, and 4, respectively, was tried. The cottonseed meal fed Lot 5 was moistened, placed in gallon buckets, and cooked with steam, or autoclaved, for one hour at 14 to 18 pounds pressure, in a laboratory autoclave. Lot 6 was fed a protein supplement of tankage 2 and cottonseed meal 1.

Unfortunately, an epidemic of hemorrhagic septicemia of the pneumonic type broke out in the herd during the course of the experiment. The only deaths among the pigs getting the autoclaved cottonseed meal, those receiving the mixture of tankage and cottonseed meal, or among 96 head on another

experiment which was in progress at the time, occurred between February 24 and March 12, during the outbreak of the disease. Although some of the pigs in the lots receiving untreated cottonseed meal died before and some after this period, the disease largely vitiated the worth of the experiment. Although iron citrate is soluble and, theoretically, iron oxide is not, in this one trial of an inconclusive nature, the expensive iron citrate showed no advantage over the inexpensive iron oxide. The mortality was the same, and both the rate of gain and the amount of gain per unit of feed slightly favored the ration containing the iron oxide.

EXPERIMENT 2

Eight lots of 10 pigs each were included in the second experiment. With the exception of one Duroc Jersey in each lot, the pigs were grade Poland China and grade and cross-bred Spotted Poland Chinas, purchased in the community. They averaged approximately 40 pounds in weight when started on the experiment, June 26, 1929. Since there was considerable variation in their initial weights, each lot was divided into two groups of five pigs each, according to size, and records kept of the feed consumed by each group. Each lot was continued until it averaged approximately 200 pounds in weight. The pigs were hand fed a full feed twice daily. In this and the other experiments as well, unless otherwise noted, they were confined indoors in pens floored with concrete and having wooden inlays for beds.

The special cottonseed meal used was developed by the Procter and Gamble Company, who cooperated in the experiment. Both the regular and special cottonseed meals were made from seed from the same source. They contained 40.2 and 40.4 per cent of protein, respectively.

The kind of feeds and the proportion of each fed to the various lots are shown in Table 1. The proportions were such as would give a nutritive ratio of approximately 1:5.1. The minerals were fed at whatever level was necessary to give a total ash content of from 4.8 to 4.9 per cent. The ingredients in the mineral mixture and their ratios are given in a footnote of the table.

In order to bring out more clearly any differences which might exist between the regular and special meals, the cottonseed meal was fed at a constant level throughout the experiment, rather than reduced as the pigs became heavier.

As a result of their studies, Dowell and Menaul (12), of the Oklahoma Station, and later Gallup (16), of the same institution, concluded that cottonseed meal could be made a safe feed for swine, and probably other livestock as well, by autoclaving or steaming the meal until it was thoroughly cooked. To verify their findings, Lot 8 was fed the same as Lot 3, except that the cottonseed meal for them was autoclaved for one hour. In this and the subsequent experiments, the procedure followed was to add just sufficient water to moisten the meal, place it in shallow trays about 2 inches deep, and autoclave it at 14 pounds pressure in a large commercial cooker, such as is used in canning factories.

Although the rations containing no alfalfa, fed to Lots 1 and 2, were considered deficient in vitamin D, none of the pigs in Lot 2 developed rickets, and it was not until they had been on feed for approximately 6 months that two of the three pigs left in Lot 1 became lame or crampy or showed any pronounced symptoms of rickets. Even when pigs are confined indoors, a vitamin-D deficiency does not show up as quickly or readily in summer and fall feeding as in winter and spring feeding.

TABLE 1.—Experiment 2

Started June 26, 1929 Pigs confined indoors and full fed twice daily	1 Corn **Cottonseed meal** Minerals	2 Corn **Special cottonseed meal** Minerals	3 Corn **Cottonseed meal** Alfalfa Minerals	4 Corn **Special cottonseed meal** Alfalfa Minerals	5 Corn **Cottonseed meal** **Tankage** Alfalfa Minerals	6 Corn **Special cottonseed meal** **Tankage** Alfalfa Minerals	7 Corn **Tankage** Alfalfa Minerals	8 Corn **Autoclaved cottonseed meal** Alfalfa Minerals
Av. per cent of cottonseed meal	**22**	**22**	**21**	**21**	**9**	**9**		**21**
No. of pigs at start	10	10	10	10	10	10	10	10
No. of deaths	**7***	**0**	**5†**	**1**	**0**	**0**	**0**	**0**
Initial weight per pig, lb.	39.9	39.8	39.6	39.6	39.8	39.9	39.8	39.3
Final weight per pig, lb.	191.5	199.5	197.8	206.8	195.1	212.5	212.4	211.9
Av. daily gain, lb.	**0.60**	**1.04**	**0.78**	**0.98**	**1.17**	**1.30**	**1.21**	**1.03**
Days required to gain 160 lb.	266	154	205	164	137	123	132	156
Daily feed per pig, lb.:								
Corn, yellow	2.27	3.36	2.78	2.96	3.73	4.11	3.98	3.45
Cottonseed meal	0.66	0.98	0.80	0.85	0.44	0.48		0.99
Tankage					0.29	0.32	0.54	
Ground alfalfa			0.11	0.12	0.14	0.16	0.14	0.14
Minerals	0.07	0.11	0.09	0.09	0.09	0.10	0.08	0.11
Total	**3.00**	**4.45**	**3.78**	**4.02**	**4.69**	**5.17**	**4.74**	**4.69**
Feed per 100 lb. gain, lb.:								
Corn	376.17	324.12	356.18	303.38	319.11	316.50	329.16	335.58
Cottonseed meal	109.61	94.44	102.74	87.50	37.33	37.03		96.79
Tankage					24.88	24.68	44.73	
Ground alfalfa			14.54	12.38	12.04	11.94	11.77	13.70
Minerals	12.46	10.73	11.14	9.49	8.03	7.96	6.67	10.50
Total	**498.24**	**429.29**	**484.60**	**412.75**	**401.39**	**398.11**	**392.33**	**456.57**
Cost of feed per 100 lb. gain	$ 5.86	$ 5.05	$ 5.64	$ 4.80	$ 4.77	$ 4.73	$ 4.75	$ 5.31

*One of the three remaining pigs weighed 125 pounds on December 11 and 109 pounds in January 8; thus, it was figured as removed December 11.
†One of the five remaining pigs died the day following the date to which the data for the lot were summarized.
Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.
Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; tankage, $2.10; ground alfalfa, $0.80; minerals, $1.50; grinding corn, 10¢.

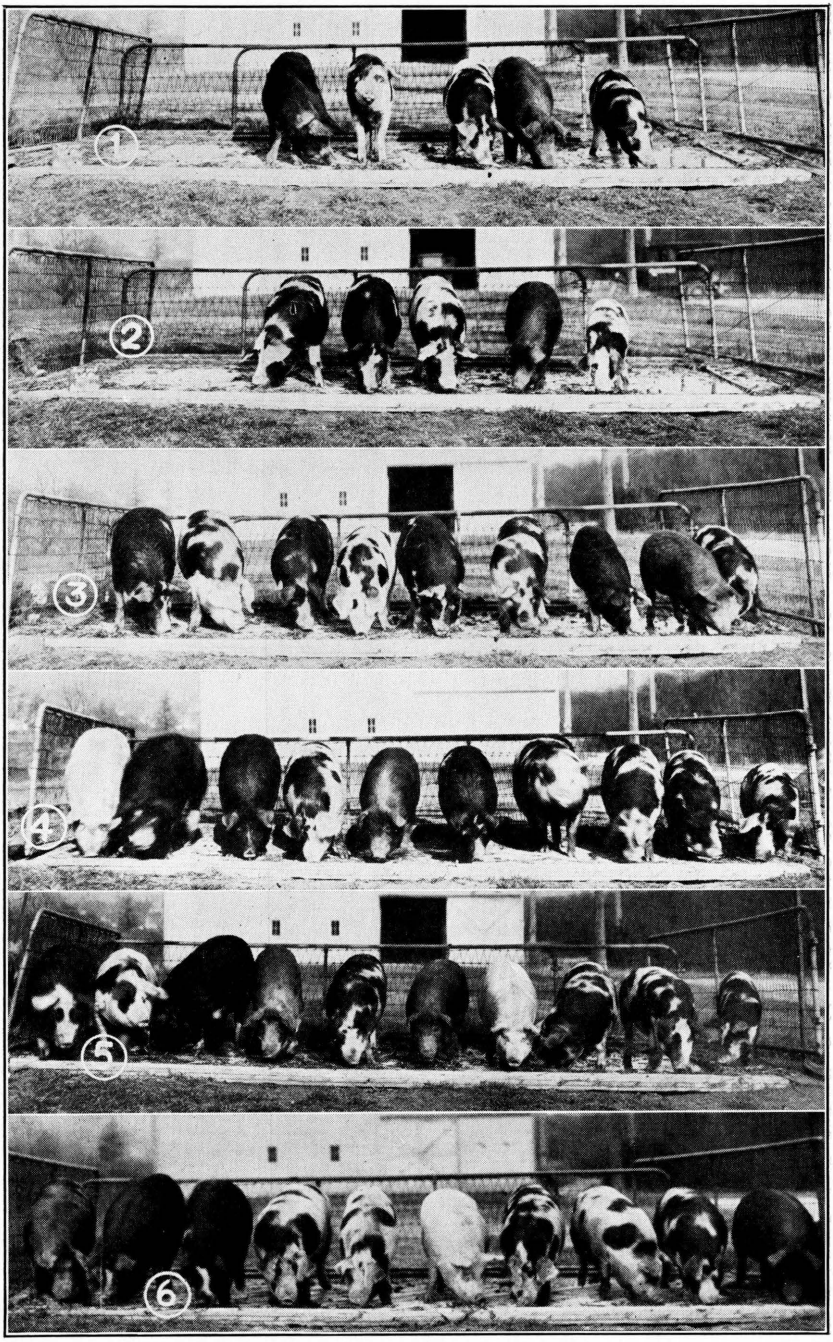
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Fig. 1

(1) Lot 1, Experiment 2; after 20 weeks. Yellow corn, 75.5; cottonseed meal, 22; minerals, 2.5. Deaths, 7. Daily gain of pigs remaining at close, 0.64 lb. Feed per 100 lb. gain, 498 lb.

(2) Lot 3, Experiment 2; after 20 weeks. Yellow corn, 73.5; cottonseed meal, 21.2; ground alfalfa, 3; minerals, 2.3. Deaths, 6. Daily gain of pigs remaining at close, 0.88 lb. Feed per 100 lb. gain, 485 lb.

(3) Lot 4, Experiment 2; after 20 weeks. Yellow corn, 73.5; special cottonseed meal, 21.2; ground alfalfa, 3; minerals, 2.3. Deaths, 1. Daily gain of pigs remaining at close, 1.00 lb. Feed per 100 lb. gain, 413 lb.

(4) Lot 5, Experiment 2; after 20 weeks. Yellow corn, 79.5; cottonseed meal, 9.3; tankage, 6.2; ground alfalfa, 3; minerals, 2. Deaths, 0. Daily gain, 1.17 lb. Feed per 100 lb. gain, 401 lb.

(5) Lot 8, Experiment 2; after 20 weeks. Yellow corn, 73.5; autoclaved cottonseed meal, 21.2; ground alfalfa, 3; minerals, 2.3. Deaths, 0. Daily gain, 1.03 lb. Feed per 100 lb. gain, 457 lb.

(6) Lot 7, Experiment 2; after 20 weeks. Yellow corn, 83.9; tankage, 11.4; ground alfalfa, 3; minerals, 1.7. Deaths, 0. Daily gain, 1.21 lb. Feed per 100 lb. gain, 392 lb.

At the levels at which it was fed to Lots 1 and 3, the regular cottonseed meal proved toxic to the pigs. Seven pigs out of the 10 in Lot 1 died. Their deaths occurred after they had been on the cottonseed meal ration for 51, 60, 97, 98, 149, and 154 days, respectively. Five pigs in Lot 3 died. Their deaths occurred on the 72nd, 74th, 76th, 82nd, and 135th day, respectively. One of the five remaining pigs died the day following the date to which the data were summarized, or on the 183rd day.

The pigs suffering from cottonseed meal injury became pale and anemic in appearance. Practically all of those that died went off feed a few days earlier and showed labored breathing as manifested by a jerking movement of the flanks. As a rule, their coats were comparatively smooth, and, aside from the anemic appearance, the pigs appeared to be normal up to within a few days before their death. The pigs which died were ordinarily those which had been making good gains up to within a week or so of their death. In some instances, pigs which showed symptoms of cottonseed meal injury would remain off feed several weeks, and then, perhaps because of the reduced feed consumption and lowered intake of the toxic principle, would begin to eat again, would improve, and once more would make fair gains.

Post-mortem examinations revealed some apparently rather characteristic symptoms of cottonseed meal poisoning. The peritoneal cavity usually contained a yellowish or amber-colored fluid. Sometimes, a gelatinous or jelly-like material of the same color was present. The small intestines and mesentery were ordinarily more or less inflamed. Most of the livers appeared to be somewhat enlarged. The amber-colored fluid was frequently found in the pleural cavity and sometimes in the pericardial cavity. The heart was often rather flabby. The lungs of some of the animals were somewhat congested; whereas those of others were practically normal.

In Texas Bulletin 410, Dr. R. C. Dunn gives the following description of lesions due to cottonseed meal poisoning: "Macroscopic lesions on post-mortem examination; pleural and peritoneal cavities, excessive quantities of a serous fluid; heart dilated and flabby; lungs congested and edematous, liver enlarged and passive congested; spleen congested; kidneys congested; lymph glands, when affected, congested and swollen."

No deaths occurred among the pigs in Lot 2 getting the special cottonseed meal but no ground alfalfa. They gained 72.8 per cent more rapidly and required 10.2 per cent less feed per unit of gain than those of Lot 1 on a similar ration containing the regular cottonseed meal.

For some reason, possibly the individuality of the animals, the pigs of Lot 4, getting alfalfa along with a ration otherwise the same, failed to gain as rapidly as those of Lot 2. In spite of their slower gains, however, they required less feed per 100 pounds of gain produced. After 16 weeks, one pig in the lot died, showing the characteristic symptoms of cottonseed meal poisoning. Although there were 13 fatalities in all among the pigs receiving the regular cottonseed meal, this was the only one among those receiving the special meal.

When the cottonseed meal was reduced to 9.3 per cent of the ration and sufficient tankage to supply an equivalent amount of protein was added, no ill effects from feeding the regular cottonseed meal were observed. During the first 14 weeks of the experiment, the pigs of Lot 5 receiving the regular meal made slightly greater gains from a given amount of feed than those of Lot 6, receiving the special meal. By the close of the experiment the average amount of feed consumed per unit of gain by the two lots was practically the same.

The results of feeding cottonseed meal without and with tankage agree with those obtained by Hale, reported in Texas Bulletin 410, in indicating that a cottonseed meal which causes losses at a higher level can be fed with safety at the rate of approximately 9 per cent of the total ration. Even though 1.5 pounds of cottonseed meal to 1 pound of tankage were fed, the mixtures compared favorably with tankage alone for supplementing yellow corn, ground alfalfa, and minerals.

In contrast with a mortality of 50 per cent among the pigs of Lot 3 which were fed yellow corn, regular cottonseed meal, ground alfalfa, and minerals, no deaths occurred among the pigs of Lot 8, fed a similar ration except that the cottonseed meal was autoclaved. During the first 8 weeks of the trial the lots getting the untreated and the autoclaved meal required 445 and 474 pounds of feed, respectively, for each 100 pounds of gain produced. Each made an average daily gain of 0.61 pound. By the end of 10 weeks Lot 3 was showing the injurious effects of the untreated meal.

EXPERIMENT 3

Fall pigs of Duroc Jersey breeding were used in the third experiment. Regular and special cottonseed meals were again compared for feeding without and with tankage in rations made up of yellow corn, ground alfalfa, and minerals. Before and after the pigs averaged 120 pounds in weight, they were fed whatever amounts of supplement were needed to provide rations containing 15.4 and 14.2 per cent of total protein, respectively. The total ash or mineral content of the various rations for the two periods, as named, ranged from 4.8 to 5 per cent and from 4.5 to 4.7 per cent. The alfalfa constituted 3 per cent of the total feed. Hand feeding was practiced.

Four of the nine pigs in Lot 2, which received 20 per cent of cottonseed meal for 98 days and 16 per cent thereafter, died during the experiment. Their deaths occurred on the 49th, 53rd, 64th, and 131st days of the test. All showed both ante-mortem and post-mortem symptoms of cottonseed meal poisoning.

Two pigs in Lot 3, getting the special cottonseed meal at the same levels, died, apparently from cottonseed meal poisoning. They had been on feed 55 and 99 days, respectively.

Thinking that possibly the higher feed requirement per unit of gain during the early part of the second experiment was caused by the cooking process, autoclaving the meal for a half hour instead of a full hour was tried. Two of the pigs on the autoclaved meal died during an outbreak of "flu" or hemorrhagic septicemia of the pneumonic type, which occurred during the 19th week of the experiment and affected practically all of the pigs on the test. The effect of the disease upon the gains of the pigs is shown by the composite growth curves presented in Figure 2. Since the two pigs which died had extremely high temperatures and since post-mortem examinations revealed hemorrhagic lesions but not the lesions of cottonseed meal poisoning, their deaths were thought to have resulted from the disease rather than from the feeding of cottonseed meal.

As shown by a lack of deaths, more rapid growth, and greater gains from a given amount of feed, mixtures of equal parts of cottonseed meal and tankage, by weight, were an improvement over cottonseed meal alone as the protein supplement. The cottonseed meal fed in this way made up 7.5 per cent of the ration until the pigs reached the 120-pound weight and 6 per cent thereafter.

TABLE 2.—Experiment 3

Started Jan. 7, 1930	1 Corn **Autoclaved cottonseed meal** Alfalfa Minerals	2 Corn **Cottonseed meal** Alfalfa Minerals	3 Corn **Special cottonseed meal** Alfalfa Minerals	4 Corn **Cottonseed meal Tankage** Alfalfa Minerals	5 Corn **Special cottonseed meal Tankage** Alfalfa Minerals	6 Corn **Oats** **Special cottonseed meal** Alfalfa Minerals	7 Corn **Special cottonseed meal Soybean oilmeal** Alfalfa Minerals	8 Corn **Tankage Linseed meal** Alfalfa Minerals
Av. per cent of cottonseed meal	**18**	**18**	**18**	**7**	**7**	**15**	**8**	.....
No. of pigs at start	9	9	9	9	9	9	9	9
No. of deaths	**2***	**4**	**2**	**0**	**0**	**0**	**0**	**0**
Initial weight per pig, lb.	54.7	54.9	54.9	55.5	54.5	55.5	55.2	54.9
Final weight per pig, lb.	207.2	206.3	199.9	201.1	202.2	206.6	205.5	204.9
Av. daily gain, lb.	**0.75**	**0.75**	**0.77**	**0.95**	**0.92**	**0.94**	**0.93**	**0.97**
Days required to gain 160 lb.	199	199	196	159	164	160	161	154
Daily feed per pig, lb.:								
Corn, yellow	2.86	2.80	2.84	3.69	3.48	2.62	3.10	3.56
Oats or linseed meal	.....	.....	.....	.....	.....	0.91	.....	0.19
Cottonseed meal	0.66	0.67	0.67	0.30	0.29	0.69	0.31	.....
Tankage or soybean oilmeal	.....	.....	.....	0.30	0.29	.....	0.31	0.37
Ground alfalfa	0.11	0.11	0.11	0.13	0.13	0.13	0.12	0.13
Minerals	0.09	0.08	0.08	0.09	0.08	0.09	0.10	0.07
Total	**3.72**	**3.66**	**3.70**	**4.51**	**4.27**	**4.44**	**3.95**	**4.32**
Feed per 100 lb. gain, lb.:								
Corn	379.29	371.36	370.51	389.92	379.51	279.17	332.28	365.38
Oats or linseed meal	.....	.....	.....	.....	.....	96.77	.....	19.21
Cottonseed meal	88.06	88.56	86.86	31.75	31.33	73.13	33.58	.....
Tankage or soybean oilmeal	.....	.....	.....	31.75	31.33	.....	33.58	38.42
Ground alfalfa	14.81	14.57	14.49	14.30	13.95	14.18	12.68	13.32
Minerals	11.35	11.17	11.11	9.06	8.83	9.46	10.57	7.54
Total	**493.51**	**485.66**	**482.96**	**476.78**	**464.95**	**472.71**	**422.69**	**443.87**
Cost of feed per 100 lb. gain	$ 5.69	$ 5.61	$ 5.58	$ 5.65	$ 5.52	$ 5.46	$ 4.97	$ 5.39

*These two pigs died on the 135th and 138th days of the experiment, during an outbreak of hemorrhagic septicemia of the pneumonic type, and showed symptoms of the disease rather than of cottonseed meal injury.

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢; oats, 32¢ a bu.; cottonseed meal, $1.40 a 100 lb.; linseed meal, $1.80; soybean oilmeal, $1.75; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢; grinding oats, 15¢.

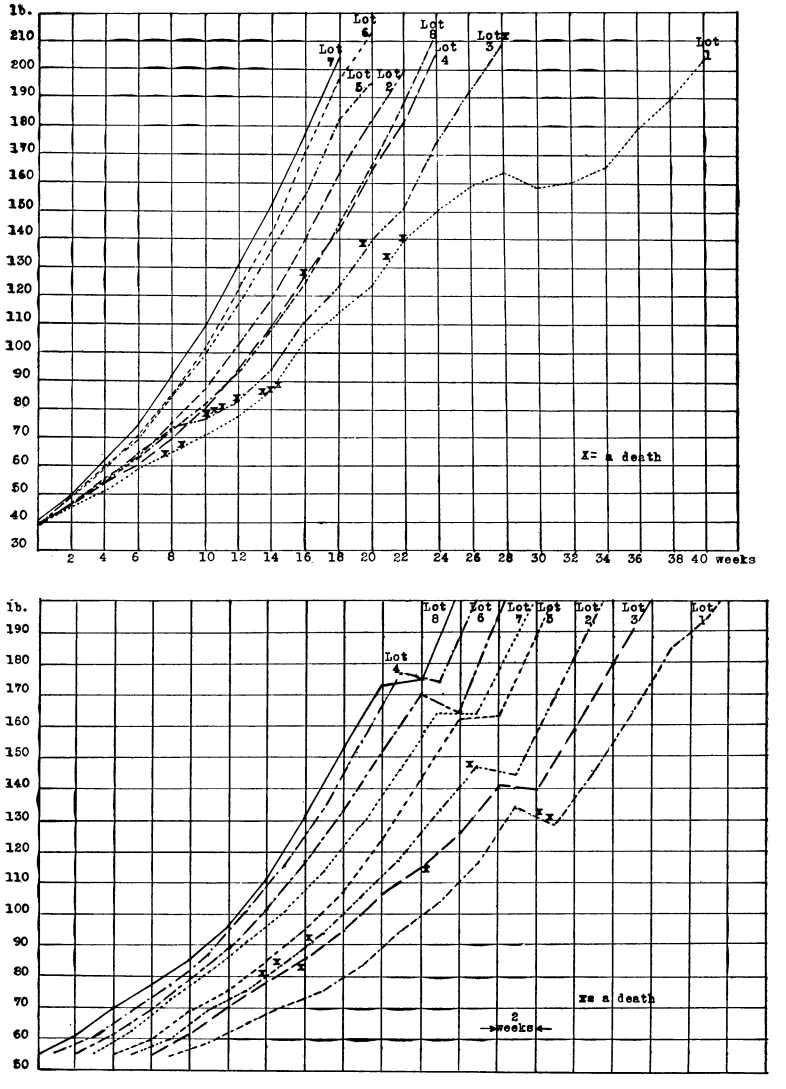

Fig. 2.—Composite growth curves of groups of pigs in Experiment 2 (upper) and Experiment 3 (lower)

A pound of ground oats for each pound of the supplemental mixture of special cottonseed meal, ground alfalfa, and minerals was fed Lot 5. Except for the oat hulls, which have little or no nutritive value, the pigs on this ration and those on the one of corn, tankage, linseed meal, ground alfalfa, and minerals required approximately the same amount of feed per unit of gain produced.

Soybean oilmeal and special cottonseed meal in equal parts, by weight, made an effective protein supplement. The pigs receiving it failed to gain quite as rapidly but required even less feed per unit of gain than those on the check ration of corn, the trio mixture, and minerals. Before and after the pigs averaged 120 pounds in weight, the cottonseed meal and soybean oilmeal each made up 8.8 and 7.0 per cent of the ration, respectively.

EXPERIMENT 4

Spring pigs of Duroc Jersey breeding from the Station herd were used in the fourth trial. Eleven lots of eight pigs each were included in the test. The rations fed are shown in Table 3. The feeds for all of the lots were mixed and self fed. A pig in each of Lots 1, 4, 5, and 8 did poorly, or gained slowly, from the beginning of the experiment. Since this was obviously due to some cause other than the feed received, they were removed from the lots as indicated in the table.

TABLE 3.—Experiment 4

Experiment started July 1, 1930 Feeds mixed and self fed. Pigs confined indoors.	1 Corn **Autoclaved cottonseed meal** Ground alfalfa Minerals	2 Corn **Cottonseed meal** Ground alfalfa Minerals	3 Corn **Cottonseed meal Tankage** Ground alfalfa Minerals	4 Corn **Cottonseed meal Tankage Cocoanut meal** Ground alfalfa Minerals	5 Corn **Cottonseed meal Tankage** Ground alfalfa Minerals
Av. per cent of cottonseed meal	**18.3**	**19.0**	**7.1**	**10.5**	**20.0**
No. of pigs at start	8	8	8	8	8
No. of removals	1	0	0	1	1
No. of deaths	**2**	**5**	**0**	**0**	**0**
Initial weight per pig, lb.	44.4	44.7	44.7	44.2	46.1
Final weight per pig, lb.	198.3	196.3	196.1	204.3	210.3
Av. daily gain, lb.	**0.69**	**0.55**	**0.90**	**0.99**	**1.02**
Days required to gain 160 lb.	232	291	178	162	157
Daily feed per pig, lb.:					
Corn	2.86	2.28	3.26	3.29	2.96
Cottonseed meal	0.69	0.58	0.29	0.46	0.89
Tankage	.....	.....	0.29	0.15	0.35
Cocoanut oilmeal	.....	.....	.....	0.26	.....
Ground alfalfa	0.11	0.09	0.12	0.13	0.13
Minerals	0.10	0.08	0.08	0.10	0.09
Total	**3.76**	**3.03**	**4.04**	**4.39**	**4.42**
Feed per 100 lb. gain, lb.:					
Corn	415.24	416.85	361.86	331.43	291.76
Cottonseed meal	99.76	105.12	31.63	46.54	87.09
Tankage	.....	.....	31.63	15.51	34.40
Cocoanut oilmeal	.....	.....	.....	26.59	.....
Ground alfalfa	16.37	16.59	13.37	13.29	13.06
Minerals	14.18	14.38	9.36	9.75	9.15
Total	**545.55**	**552.94**	**447.85**	**443.11**	**435.46**
Cost of feed per 100 lb. gain	$ 6.36	$ 6.46	$ 5.35	$ 5.23	$ 5.44

The pigs removed from Lots 1, 4, 5, and 8 were taken out after 14, 56, 56, and 112 days and weighed 42.5, 48.5, 48.5, and 58.5 pounds, respectively.

TABLE 3.—Experiment 4—Continued

Experiment started July 1, 1930	6 Corn	7 Corn	8 Corn	9 Corn	10 Corn	11 Corn
Feeds mixed and self fed.	Special cotton-seed meal	Special cotton-seed meal Tankage	Special cotton-seed meal Tankage Cocoanut meal	Tankage Linseed meal	Tankage Linseed meal	Cotton-seed meal*
Pigs confined indoors.	Ground alfalfa Minerals	Ground alfalfa Minerals	Ground alfalfa Minerals	Ground alfalfa Minerals	Ground alfalfa Minerals	Ground alfalfa Minerals
Av. per cent of cottonseed meal	**18.0**	**7.1**	**10.7**	.....	.....	**23.1**
No. of pigs at start	8	8	8	8	7	8
No. of removals	0	0	1	0	0	0
No. of deaths	**0**	**0**	**0**	**0**	**0**	**5**
Initial weight per pig, lb	44.4	44.3	43.9	45.0	45.5	43.9
Final weight per pig, lb	195.0	196.0	200.2	203.3	212.0	209.8
Av. daily gain, lb	**0.90**	**0.94**	**0.90**	**1.03**	**1.08**	**0.60**
Days required to gain 160 lb	178	170	178	156	148	267
Daily feed per pig, lb.:						
Corn	3.13	3.46	3.03	3.17	3.70	2.29
Cottonseed meal	0.74	0.305	0.43	.....	.....	0.74
Tankage	.....	0.305	0.15	0.17	0.424	.....
Cocoanut—or—linseed meal	.....	.....	0.24	0.67	0.212	.....
Ground alfalfa	0.12	0.13	0.12	0.12	0.14	0.10
Minerals	0.11	0.09	0.09	0.09	0.09	0.08
Total	**4.10**	**4.29**	**4.06**	**4.22**	**4.57**	**3.21**
Feed per 100 lb. gain, lb.:						
Corn	349.66	367.19	338.30	308.32	342.46	381.84
Cottonseed meal	82.57	32.40	48.36	.....	.....	123.75
Tankage	.....	32.40	16.12	16.27	39.216	.....
Cocoanut—or—linseed meal	.....	.....	27.21	65.08	19.608	.....
Ground alfalfa	13.74	13.66	13.61	12.33	12.67	16.07
Minerals	11.90	9.56	9.98	9.04	8.45	13.93
Total	**457.87**	**455.21**	**453.58**	**411.04**	**422.40**	**535.59**
Cost of feed per 100 lb. gain	$ 5.33	$ 5.44	$ 5.36	$ 5.14	$ 5.17	$ 6.08

*Lot 11 was fed expeller cottonseed meal from South Carolina containing 36 per cent of protein. The other meals were from Arkansas and contained 43 per cent of protein. The "Special cottonseed meal" was developed by the Procter & Gamble Co.

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢ a bu.; cottonseed meal, 43%, $1.45 a 100 lb.; cottonseed meal, 36%, $1.25; cocoanut meal, $1.25; tankage, $2.10; linseed meal, $1.80; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

While they were under 120 pounds in weight, the pigs in each lot, with the exception of Lot 5 as mentioned later, were fed whatever amounts of supplement were needed to provide rations containing 16 per cent of total protein. After an average weight of 120 pounds was reached, the amount of supplement was reduced so as to lower the protein content to 14.6 per cent. Each ration contained 3 per cent of ground alfalfa. The minerals fed before and after the pigs averaged 120 pounds in weight were such as would give a total ash content of approximately 5.2 and 4.9 per cent, respectively.

Regular cottonseed meal and the special meal developed by the Procter and Gamble Company, who cooperated in a part of the project, were compared for feeding (a) as the only protein concentrate in the ration, (b) with an equal

amount of tankage, and (c) with less tankage in rations containing 6 per cent of cocoanut meal. Both cottonseed meals were from Arkansas and were manufactured by the same mill. They contained 43 per cent of protein.

In Lot 2, fed the regular cottonseed meal as the only supplement, deaths occurred on the 71st, 79th, 90th, 128th, and 162nd days. The ration contained 20 per cent of cottonseed meal for the first 140 days and 15.7 per cent thereafter.

There were no mortalities among the pigs fed tankage or tankage and cocoanut meal with the regular cottonseed meal; nor were there any among the pigs in any of the lots fed the special cottonseed meal.

Lot 1 was fed the same as Lot 2, except that the cottonseed meal for it was moistened and autoclaved for a half hour at 14 pounds pressure. One pig in the lot died after being on feed 104 days and another after being on feed 181 days. Both showed symptoms of cottonseed meal poisoning.

Lot 5 was fed a ration containing tankage at a 7.9 per cent level and the untreated cottonseed meal at a high, or 20 per cent level, throughout the experiment. Although the meal was from the same supply as that fed Lot 2, although the average percentage fed was slightly greater, and although five pigs out of eight in Lot 2 died, no losses occurred among the pigs in Lot 5. Since the ration was otherwise similar to that fed Lot 2 and since the cottonseed meal was demonstrated to be toxic when used without the tankage at a slightly lower level, the tankage apparently exerted a protective influence.

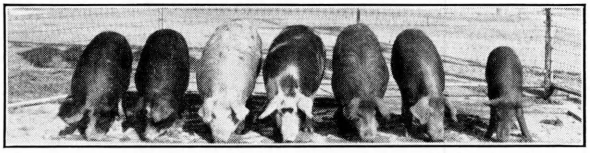

Fig. 3.—Lot 5, Experiment 4; after receiving cottonseed meal at a high level with tankage for 20 weeks. Yellow corn, 67; cottonseed meal, 20; tankage, 7.9; ground alfalfa, 3; minerals, 2.1. Deaths, 0; removals, 1. Daily gain of pigs remaining at close, 1.06. Feed per 100 lb. gain, 435 lb.

The belief has been expressed that if protein concentrates of plant origin, other than cottonseed meal, were fed in a similar way, they would have a harmful effect corresponding to that sometimes resulting from the use of cottonseed meal. The author has fed linseed meal in a number of experiments, however, with excellent results, providing minerals and some source of vitamins, such as ground alfalfa, rice polish, etc., were included in the ration. Rations of yellow corn, soybean oilmeal, ground alfalfa, and minerals were also highly satisfactory, as shown by the results of experiments which were reported in Bulletin 452 of the Ohio Agricultural Experiment Station. Although they give poor results if fed in deficient rations, not all protein-rich feeds of plant origin have a harmful effect after their mineral and vitamin deficiencies are corrected.

To secure further information concerning the worth of linseed meal for pigs, when fed at different levels, two check lots were included in the experi-

ment. Lot 9 was fed a mixture of tankage 1 and linseed meal 4. Lot 10 was fed the usual mixture of tankage 2 and linseed meal 1. The pigs of Lot 9 required even less feed per unit of gain than did the pigs of Lot 10.

Lot 11 was fed a cottonseed meal from South Carolina which contained 36 per cent of protein and was made by the expeller process. It constituted 25 per cent of the ration for the first 140 days and 20 per cent from then on, or from the time the pigs averaged 120 pounds in weight. Deaths occurred on the 47th, 68th, 69th, 73rd, and 143rd days. Apparently, manufacturing cottonseed meal by the expeller process does not necessarily make it safer than that made by the hydraulic process.

EXPERIMENT 5

Six lots of fall pigs of Duroc Jersey breeding, from the Station herd, were used in the fifth experiment. With the exception of Lot 1, which was fed cottonseed meal at a high level with tankage, rations containing approximately 16 per cent of protein were fed until the pigs averaged 120 pounds in weight. From that time on they were fed rations containing approximately 14 per cent of protein. The pigs were full fed twice daily.

To secure further data concerning the protective effect of tankage when it is fed with cottonseed meal, Lot 1 was fed tankage at an 8 per cent level and cottonseed meal at a high, or 20 per cent, level. Cottonseed meal was not fed alone at this level, as the only high-protein feed in the ration to any of the pigs, but a mixture of meals used in previous tests, containing approximately 40.6 per cent of protein and known to be toxic, was fed. The 12 pigs in the lot remained thrifty throughout the experiment.

There were 13 pigs in each of the other lots. A few of these which failed to thrive or were lacking in vigor from the beginning of the test and a few which became unthrifty during the test, apparently from causes other than the ration received, were taken out. The number removed from each lot is shown in Table 4, and a note accompanying the table gives the weight of each pig when it was taken out, as well as the date of its removal.

Lot 2 was fed a small amount of cottonseed meal, or half as much of it as of tankage. Although the pigs in this lot failed to gain quite as rapidly, they required somewhat less feed per unit of gain than the lot fed a similar ration except that it contained more cottonseed meal and less tankage.

Since it was thought that perhaps feeds other than tankage, which are reasonably high in protein, would likewise prove beneficial for feeding with cottonseed meal, hulled oats and soybean oilmeal were selected for trial. These were chosen because oats is a common crop and soybean oilmeal is a by-product of a crop which is produced in relative abundance.

One pig out of 13 receiving cottonseed meal along with hulled oats, yellow corn, ground alfalfa, and minerals died during the experiment. Its death occurred after it had been on feed for 64 days. The ration contained 18.4 per cent of cottonseed meal for the first 98 days and 13.4 per cent after that time. The pig that died was not lacking in vigor and, until shortly before its death, was one of the faster-gaining pigs in the lot.

A supplemental mixture of equal parts of cottonseed meal and soybean oilmeal caused no losses and gave fully as good results as the mixture of tankage 2 and linseed meal 1 fed the check lot.

TABLE 4.—Experiment 5

Experiment started Jan. 13, 1931	1	2	3	4	5	6
	Corn	Corn	Corn	Corn	Corn	Corn
	Tankage	Tankage	Ground hulled oats	Soybean oilmeal	Soybean oilmeal	Tankage Linseed meal
Feeds mixed and fed twice daily	Cottonseed meal Ground alfalfa Minerals	Cottonseed meal Ground alfalfa Minerals	Cottonseed meal Ground alfalfa Minerals	Cottonseed meal Ground alfalfa Minerals	Ground alfalfa Minerals	Ground alfalfa Minerals
Av. per cent of cottonseed meal	**20**	**4.1**	**15.7**	**7.9**	.....	.....
No. of pigs at start	12	13	13	13	13	13
No. of removals	0	1	3	1	3	2
No. of deaths	**0**	**0**	**1**	**0**	**0**	**0**
Initial weight per pig, lb	52.7	52.5	52.8	52.8	52.7	53.3
Final weight per pig, lb	213.7	214.1	219.3	217.6	212.1	215.3
Av. daily gain, lb	**1.15**	**1.11**	**0.84**	**1.15**	**0.88**	**1.15**
Days required to gain 160 lb	139	145	191	139	181	139
Daily feed per pig, lb.:						
Corn	3.31	3.85	2.55	3.65	3.03	3.85
Tankage or hulled oats	0.39	0.38	0.53	.....	.....	0.41
Cottonseed or linseed meal	0.98	0.19	0.61	0.366	.....	0.21—
Soybean oilmeal	.....	.....	.....	0.366	0.55	.....
Ground alfalfa	0.15	0.14	0.12	0.14	0.12—	0.14
Minerals	0.07	0.07	0.10	0.12	0.10	0.07
Total	**4.90**	**4.63**	**3.91**	**4.64**	**3.80**	**4.68**
Feed per 100 lb. gain, lb.:						
Corn	287.21	348.02	304.15	317.77	343.04	333.80
Tankage or hulled oats	34.04	34.25	62.73	.....	.....	35.41
Cottonseed or linseed meal	85.10	17.13	73.33	31.90	.....	17.71
Soybean oilmeal	.....	.....	.....	31.90	62.28	.....
Ground alfalfa	12.76	12.55	13.99	12.13	12.88	12.15
Minerals	6.38	6.27	12.12	10.51	11.16	6.08
Total	**425.49**	**418.22**	**466.33**	**404.21**	**429.36**	**405.15**
Cost of feed per 100 lb. gain	$ 5.26	$ 4.98	$ 5.61	$ 4.76	$ 5.13	$ 4.92

Removals: Lot 2, 49 lb. pig March 24; Lot 3, 65.5 lb. pig April 7 and 63.5 and 90 lb. ones April 21; Lot 4, 52.5 lb. pig February 24; Lot 5, a 52.5 and a 51 lb. pig April 7 and a 57 lb. one April 21; Lot 6, an 83.5 and a 66.5 lb. pig April 21.

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢ a bu.; ground hulled oats, $1.50 a 100 lb.; cottonseed meal, $1.40; soybean oilmeal, $1.75; linseed meal, $1.80; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

Probably because some of the pigs in the lot were lacking in thrift during the early part of the test, due to causes other than the ration received, soybean oilmeal, when fed as the only protein concentrate, did not make as good a relative showing as it made in tests reported in Bulletin 452.

Cottonseed meal was hardly as effective as linseed meal when used as a substitute for linseed meal in the trio supplemental mixture.

EXPERIMENT 6

In the sixth experiment of the series, cottonseed meal was fed at a high, or 20 per cent, level and at a low, or 4 per cent, level in a ration containing tankage, as well as yellow corn, ground alfalfa, and minerals. Cottonseed meal which was sold to contain 41 per cent of protein was fed. Vigorous, early

spring pigs of Duroc Jersey and of Yorkshire-Duroc Jersey breeding were used. They were kept in outside dirt pens, which were free of vegetation or green feed, and were self fed.

None of the nine pigs getting the ration containing 20 per cent of cottonseed meal and 8 per cent of tankage died or showed any symptoms of cottonseed meal poisoning. Whether the cottonseed meal used would have proved toxic if fed as the only high-protein feed in the ration was not determined.

Although no symptoms of poisoning were manifested, the slower gains and larger feed consumption per unit of gain of the lot getting the higher level of cottonseed meal were, possibly, indications that the cottonseed meal did exert a deleterious effect and that the inclusion of tankage in the ration did not completely overcome this harmful effect.

TABLE 5.—Experiment 6: Cottonseed Meal, at High and Low Levels, with Tankage for Pigs in Dry Lot

Started April 22, 1931	Ground corn **Tankage** **Cottonseed meal** Ground alfalfa Minerals	Ground corn **Tankage** **Cottonseed meal** Ground alfalfa Minerals
Av. per cent of cottonseed meal	**20**	**4**
No. of pigs at start	9	9
No. of deaths	**0**	**0**
Initial weight per pig, lb.	81.8	82.2
Final weight per pig, lb.	218.3	214.8
Av. daily gain, lb.	**1.15**	**1.35**
Days required to gain 150 lb.	131	111
Daily feed per pig, lb.:		
Corn	3.33	4.69
Tankage	0.39	0.44
Cottonseed meal	0.99	0.22
Ground alfalfa	0.15	0.17
Minerals	0.07	0.08
Total	**4.93**	**5.60**
Feed per 100 lb. gain, lb.:		
Corn	290.50	346.19
Tankage	34.43	32.86
Cottonseed meal	86.07	16.43
Ground alfalfa	12.91	12.43
Minerals	6.46	6.21
Total	**430.37**	**414.12**
Cost of feed per 100 lb. gain	$ 5.32	$ 4.92

The cottonseed meal used was sold to contain 41 per cent of protein.

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

EXPERIMENT 7

Fall pigs were used in the seventh experiment of the series. Lot 1 contained seven, and the others eight, pigs each at the start. The feeds for the various lots were mixed in definite proportions and were self fed. The proportions were not changed during the experiment and were such as would provide rations containing approximately 15 per cent of total protein. The kinds of feeds, percentages used, and results obtained are shown in Table 6.

TABLE 6.—Experiment 7

Started Dec. 7, 1932	1 White corn 80.0 Cottonseed meal 12.6 Tankage 4.2 Oil* 0.5 Minerals 2.7	2 Yellow corn 80.6 Cottonseed meal 12.6 Tankage 4.2 Minerals 2.6	3 Yellow corn 80.4 Cottonseed meal 11.7 Tankage 3.9 Alfalfa 4.0	4 Yellow corn 76.0 Cottonseed meal 18.4 Alfalfa 3.0 Minerals 2.6	5 Yellow corn 76.0 Autoclaved cottonseed meal 18.4 Alfalfa 3.0 Minerals 2.6
Av. per cent of cottonseed meal	**12**	**12.6**	**11.7**	**18.4**	**18.4**
No. of pigs at start	7	8	8	8	8
No. of removals	0	0	0	0	1
No. of deaths	**0†**	**0**	**0**	**3**	**0**
Initial weight per pig, lb.	58.8	59.8	59.7	60.2	60.0
Final weight per pig, lb.	191.2	206.4	208.1	198.2	208.3
Av. daily gain, lb.	**0.63**	**0.81**	**0.96**	**0.51**	**0.98**
Days required to gain 160 lb.	254	198	167	314	163
Daily feed per pig, lb.:					
Corn	2.68	3.09	3.31	2.37	3.51
Cottonseed or linseed meal	0.42	0.48	0.48	0.58	0.85
Tankage	0.14	0.16	0.16	.....	.....
Ground alfalfa or oil	0.02	.....	0.17	0.09	0.14
Minerals	0.09	0.10	.....	0.08	0.12
Total	**3.35**	**3.83**	**4.12**	**3.12**	**4.62**
Feed per 100 lb. gain, lb.:					
Corn	424.75	383.59	343.54	465.83	358.55
Cottonseed or linseed meal	66.90	59.97	49.99	112.78	86.81
Tankage	22.30	19.99	16.66	.....	.....
Ground alfalfa or oil	2.65	.....	17.09	18.39	14.15
Minerals	14.34	12.37	.....	15.93	12.27
Total	**530.94**	**475.92**	**427.28**	**612.93**	**471.78**
Cost of feed per 100 lb. gain	$ 7.27	$ 5.66	$ 4.97	$ 7.09	$ 5.46

*Refined cottonseed oil containing approximately 1 per cent of Vitex, a vitamin-D concentrate.

†The data for Lot 1 are to the close of the 30th week. By then the pigs were showing the effects of a lack of vitamin A, and three were changed to a ration containing yellow corn and cod-liver oil. One of the three died 4 days later. A pig continued on the original ration died on the 222nd day and another on the 254th day of the experiment.

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; tankage, $2.10; linseed meal, $1.80; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢; cottonseed oil, 8¢; Vitex, $25.00 a pound.

TABLE 6.—Experiment 7—Continued

	6	7	8	9
	Yellow corn 76.0 Special cotton-seed meal 18.4 Alfalfa 3.0 Minerals 2.6	Yellow corn 79.0 Special cotton-seed meal 10.4 Tankage 5.2 Alfalfa 3.0 Minerals 2.4	Yellow corn 79.0 Cottonseed meal 10.4 Tankage 5.2 Alfalfa 3.0 Minerals 2.4	Yellow corn 80.8 Linseed meal 4.6 Tankage 9.2 Alfalfa 3.0 Minerals 2.7
Av. per cent of cottonseed meal	**18.4**	**10.4**	**10.4**	.....
No. of pigs at start	8	8	8	8
No. of removals	2	2	1	0
No. of deaths	**0**	**0**	**0**	**0**
Initial weight per pig, lb	60.4	60.4	59.7	60.7
Final weight per pig, lb	215.7	207.7	206.3	212.1
Av. daily gain, lb	**0.75**	**1.08**	**0.84**	**1.20**
Days required to gain 160 lb	214	148	191	134
Daily feed per pig, lb.:				
Corn	3.24	4.00	3.29	3.95
Cottonseed or linseed meal	0.79	0.53	0.43	0.22
Tankage	.....	0.27	0.22	0.45
Ground alfalfa or oil	0.13	0.15	0.13	0.15
Minerals	0.11	0.12	0.10	0.13
Total	**4.27**	**5.07**	**4.17**	**4.90**
Feed per 100 lb. gain, lb.:				
Corn	433.47	369.14	390.54	328.80
Cottonseed or linseed meal	104.95	48.60	51.41	18.72
Tankage	.....	24.30	25.71	37.44
Ground alfalfa or oil	17.11	14.02	14.83	12.21
Minerals	14.83	11.21	11.86	10.99
Total	**570.36**	**467.26**	**494.35**	**408.16**
Cost of feed per 100 lb. gain	$ 6.60	$ 5.53	$ 5.85	$ 5.00

An 85 lb. pig was taken out of Lot 5 after 56 days because of hernia.

A 61 lb., unthrifty pig was removed from Lot 6 after 98 days but was continued on the same ration. From then until the lot was discontinued, 10 weeks later, it gained 0.47 lb. daily and consumed 4.58 pounds of feed for each pound of gain produced. A 66 lb., mangy pig was taken out of Lot 6 on the 84th day.

A pig in Lot 7 became injured and the others fought it to such an extent as to necessitate its removal on the 56th day, at a weight of 117.5 lb. Another pig which failed to gain after the first 2 weeks, apparently due to no fault of the ration, was removed at the close of the 12th week. It was figured as removed at its maximum weight of 60 lb. on the 14th day. No deduction was made for the feed it consumed thereafter.

A pig in Lot 8 developed a crooked legged condition and was taken out on the 70th day at a weight of 84 lb.

Yellow corn was fed to all of the pigs except those in Lot 1. Lot 1 was fed white corn, cottonseed meal, tankage, refined cottonseed oil containing Vitex, and minerals. Vitex is a vitamin-D concentrate having a potency 150 times that of cod-liver oil. The intention was to supply a ration which would be low in vitamin A but adequate insofar as the other vitamins, proteins, and minerals were concerned.

The pigs in Lot 1 made fair gains and showed no marked symptoms of a deficiency in the ration until they had been on feed for a period of 24 weeks. By the 26th week five pigs out of the seven were affected or showed the consequences of a lack of vitamin A in their feed. They rose with difficulty, stood with their legs spread apart to prop themselves, and walked with a staggering gait. Their ears drooped to an abnormal extent, vision was impaired, and there was a general lack of muscular coordination. Although it had previously had a well arched back, one pig developed a marked drooping and curving of the back, which was especially pronounced when it walked.

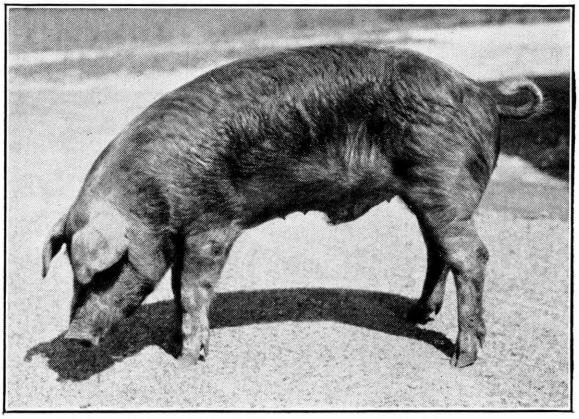

Fig. 4.—Pig from Lot 1, Experiment 7; after 29 weeks. Suffering from a lack of vitamin A. Symptoms: Impaired vision, staggering gait, abnormal drooping of ears, general lack of muscular coordination. One pig showed a pronounced drooping and curving of the back. All rose with difficulty and, when standing, would spread their legs to prop themselves. Ration: White corn, 80; cottonseed meal, 12.6; tankage, 4.2; cottonseed oil and Vitex [to supply vitamin D], 0.5; minerals, 2.7.

The symptoms were apparently not greatly different from those described as sometimes occurring among cattle that have been fed relatively large amounts of cottonseed meal for rather long periods of time, but they were distinctly different from the symptoms manifested by the pigs suffering from cottonseed meal poisoning in this series of tests.

At the beginning of the 31st week three of the affected pigs were changed to a ration of yellow corn 79.5, cottonseed meal 12.6, tankage 4.2, cod-liver oil 1.0, and minerals 2.7. Both yellow corn and cod-liver oil contain vitamin A. One of the three pigs which had lost 26.5 pounds in weight during the preceding

6 weeks died 4 days later, or before sufficient time had elapsed for it to respond to the change in feed. Of the two remaining pigs, one had lost 2.5 pounds and the other had gained only 2 pounds during the 6 weeks preceding the change. During the 6 weeks following the change, they gained 48 and 56 pounds, respectively, and consumed an average of 328 pounds of feed for each 100 pounds of gain produced.

One of the four pigs continued on the white corn ration died on the 222nd day of the experiment, or 12 days after the removal of the three. One gained 32.5 pounds during the 6-week period and showed no pronounced symptoms of a lack of vitamin A. The third one gained only 4.5 pounds and the fourth one lost 40.5 pounds in the 42 days. The first three had gained 11.5, 39.5, and 26.5 pounds, respectively, and the fourth had lost 17 pounds during the preceding 42 days.

The experiment with Lot 1 was discontinued at the close of the 6-week period, or after the pigs had been on feed for a total of 36 weeks. The pig that had lost 40.5 pounds in weight during the last 42 days died 2 days after the close of the experiment. Figure 6 shows the individual growth curves of the seven pigs.

No alfalfa was included in the ration of yellow corn, cottonseed meal, tankage, and minerals fed Lot 2. This ration was expected to be somewhat low in vitamin D, the antirachitic vitamin. The pigs did not gain as rapidly as those in some of the other lots, but none of them became crampy or developed any pronounced symptoms of rickets, nor did any of them die during the course of the experiment.

Four per cent of ground alfalfa but no minerals were included in the ration fed Lot 3. The ration was intended to be low in minerals and adequate in other respects. Since both tankage and alfalfa have a fairly high ash or mineral content, possibly the ration was not lacking materially in this respect. The pigs in the lot remained healthy and vigorous, made comparatively rapid gains, and consumed a relatively small amount of feed per unit of gain.

No tankage or other high-protein feed was fed with the cottonseed meal to the pigs in Lot 4. Three pigs in the lot died after they had been on feed for periods of 52, 72, and 88 days, respectively. At one time or another, three of the five remaining pigs showed a thumping condition, or symptoms of cottonseed meal injury. All of them manifested a loss of appetite. Perhaps, because of this and the resulting low intake of cottonseed meal, the pigs improved and later took more nearly normal quantities of feed again.

For the first 8 weeks, an average of 2.78 pounds of feed a head was consumed daily. For the next 14 weeks the lot took only 2.24 pounds of feed daily a head and made an average daily gain of only 0.3 pound. For the subsequent 14 weeks, or the remainder of the test, the feed consumption was 4.4 pounds and the rate of gain 0.85 pound daily a head.

Lot 5 was fed the same as Lot 4 except that the cottonseed meal was moistened and autoclaved for one hour at 14 pounds pressure. The results obtained from the autoclaved meal were in marked contrast to those obtained from the untreated meal. No pigs died. The rate of gain was increased from 0.51 to 0.98 pound daily a head, and the feed consumption per 100 pounds of gain was lowered from 613 to 472 pounds. Moistening the meal and autoclaving it for an hour apparently made it an entirely safe feed.

Special cottonseed meal was fed to Lot 6; otherwise, the ration was similar to that fed Lot 4. Two pigs in the lot did so much more poorly than the other six that there seemed little question as to their lack of vigor being due to some

cause other than the ration fed. One of them was removed from the lot on the 84th day; the second one was placed in a separate pen on the 98th day but was continued on the same ration. Although the record of its gain and feed consumption was not included with that of the others, it was alive and much improved on May 24, the date to which the data for those remaining in the lot were summarized.

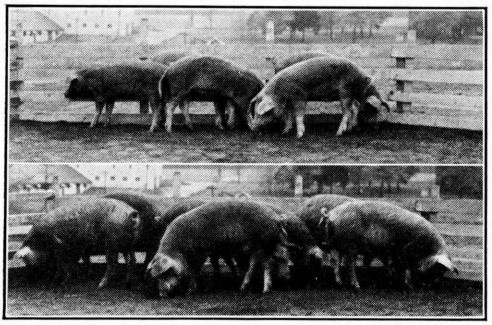

Fig. 5.—(Above).—Lot 4, Experiment 7; after 22 weeks. Yellow corn, 76; cottonseed meal, 18.4; ground alfalfa, 3; minerals, 2.6. Deaths, 3. Daily gain of pigs remaining at close, 0.56 lb. Feed per 100 lb. gain, 613 lb. (Below).—Lot 5, Experiment 7; after 22 weeks. Yellow corn, 76; autoclaved cottonseed meal, 18.4; ground alfalfa, 3; minerals, 2.6. Deaths, 0. Daily gain, 0.98 lb. Feed per 100 lb. gain, 472 lb.

The protein supplement for Lot 7 consisted of special cottonseed meal 2 and tankage 1. One pig in the lot became injured in some way, and consequently the others fought it to such an extent as to necessitate its removal. When taken out, it was the third heaviest pig in the group. Another pig in the lot did very poorly, apparently from no fault of the ration, and so was taken out at the close of the 12th week. This pig was probably responsible for the lot showing a rather high feed requirement per unit of gain. From March 1 to April 19, or after its removal, the lot gained 1.7 pounds daily a head and consumed an average of 347 pounds of feed for each 100 pounds of gain produced. While of similar weight, 118 to 212 pounds, those in the check lot fed a protein supplement of tankage and linseed meal gained 1.68 pounds daily a head and consumed 382 pounds of feed for each 100 pounds of gain produced.

Regular, instead of special, cottonseed meal was fed to Lot 8. This was the only respect in which their ration differed from that of Lot 7. A pig which developed a cycle-hocked, or crooked-legged, condition was taken out of the lot at the close of the 12th week. The condition was so severe that the pig made no gain during the last 2 weeks it was in the lot. From the time of its removal, or while the others were between 127 and 206 pounds in weight, they gained 1.08 pounds daily a head and consumed 482 pounds of feed for each 100 pounds of gain. Although there were no deaths in the lot, the cottonseed meal, at the level at which it was fed, apparently had a slightly deleterious effect on the pigs, in spite of the presence of tankage in the ration.

EXPERIMENT 8

Mixtures of equal parts of autoclaved cottonseed meal and tankage and of equal parts of linseed meal and tankage were compared for feeding with yellow corn, ground alfalfa, and minerals in Experiment 8. The cottonseed meal was moistened and autoclaved or cooked with steam, under 14 pounds pressure, for one hour. It was then mixed with the other feeds, which took up the excess

moisture in the cottonseed meal. All of the feeds in each ration were mixed together, and the mixtures were self fed. The percentage of protein feeds in the ration was reduced when the pigs averaged 125 pounds in weight. Dry-rendered tankage was fed.

In all of the writer's experience with the feeding of yellow corn to pigs not on pasture, no evidence of any marked deficiency of vitamin A has been observed. Nevertheless, in order to secure further data as to the role of vitamin A, if any, in cottonseed meal injury in pigs, a third group in the experiment was fed a mixture of yellow corn, cottonseed meal, ground alfalfa, minerals, and cod-liver oil—a ration which was especially rich in vitamin A.

TABLE 7.—Experiment 8

Started May 3, 1933	1 Corn **Tankage** **Autoclaved cottonseed meal** Ground alfalfa Minerals	2 Corn **Tankage** **Linseed meal** Ground alfalfa Minerals	3 Corn **Cottonseed meal** Ground alfalfa Minerals Cod-liver oil
Av. per cent of cottonseed meal	**6.6**	.....	**19.1**
No. of pigs at start	15	15	8
No. of removals	1	1	0
No. of deaths	**0**	**0**	**3**
Initial weight per pig, lb	56.7	56.7	56.5
Final weight per pig, lb	200.0	208.8	210.1
Av. daily gain, lb	**1.09**	**1.44**	**0.63**
Days required to gain 160 lb	147	111	254
Daily feed per pig, lb.:			
Corn	3.56	4.37	2.44
Cottonseed or linseed meal	0.29	0.38	.....
Tankage	0.29	0.38	0.62
Ground alfalfa	0.18	0.22	0.10
Minerals	0.09	0.11	0.08
Cod-liver oil	.....	.....	0.02
Total	**4.41**	**5.46**	**3.26**
Feed per 100 lb. gain, lb.:			
Corn	326.61	303.64	386.32
Cottonseed or linseed meal	26.62	26.24	.....
Tankage	26.62	26.24	98.60
Ground alfalfa	16.19	15.17	15.49
Minerals	8.68	8.00	13.43
Cod-liver oil	.....	.....	2.58
Total	**404.72**	**379.29**	**516.42**
Cost of feed per 100 lb. gain	$ 4.88	$ 4.70	$ 6.27

Minerals: Salt, 19.37; limestone, 38.8; special steamed bone meal, 38.8; iron oxide, 2.8; anhydrous copper sulfate, 0.2; potassium iodide, 0.03.

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; linseed meal, $1.80; dry-rendered tankage, $2.45; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢; cod-liver oil, 12¢ a lb.

There were 15 pigs in each of the first two lots and eight in the third. A 96-pound pig in Lot 2 died on the 37th day of the experiment from overheating, after having been driven outdoors and sprayed with crude oil to destroy the lice. An unthrifty pig weighing 51.5 pounds was taken out of Lot 1 at the close of the 10th week. The 14 remaining in the lot, when an average weight

of 200 pounds was reached, made an average daily gain of 1.13 pounds. That they grew less rapidly and made less gain per unit of feed consumed than the pigs receiving linseed meal was at least partially due to their lower feed consumption. Whether the ration was less palatable because of the manner in which it was prepared and fed or for some other reason, however, is not known.

For the first 22 weeks cottonseed meal from the same supply as that used in Experiment 7, which was started during the preceding winter, was fed. The ration for Lot 3 contained 22 per cent of cottonseed meal for the first 16 weeks and 16.6 per cent thereafter. By the 16th week, three of the pigs were seriously affected and showing the thumping condition, which is a characteristic symptom of the later stages of cottonseed meal injury.

Since the original supply was exhausted, a different brand of cottonseed meal was fed after the 22nd week. One pig died on the 176th day and two others on the 179th day of the experiment. Each of the three showed typical ante- and post-mortem symptoms of cottonseed meal poisoning. The peritoneal cavity of one contained an unusual amount of the characteristic yellow or amber-colored fluid and of the gelatinous material of the same color. All showed enlarged hearts and an inflamed condition of the small intestines and mesentery.

By the close of the experiment, only one pig had shown no ill effects from the ration. It grew normally throughout the feeding period and made an average gain of 1.25 pounds daily. Figure 6 compares the individual growth curves of the pigs in Lot 3 with the composite growth curves of the more or less normal pigs in Lots 1 and 2. Slow-gaining pigs are not necessarily the first to succumb to cottonseed meal injury. Not infrequently a pig which has become affected eats very little feed; consequently, the toxic material consumed is materially reduced and the animal's life is prolonged. In other instances, a pig may eat fairly liberal quantities of feed and continue to gain up to within a day or so of its death.

A sample of the cottonseed meal fed in Experiment 7 and also in Experiment 8, for 22 weeks, was sent to Dr. J. O. Halverson, of the North Carolina Experiment Station. He found that the meal, when moistened, contained approximately 0.082 per cent of gossypol. Since an average of 18.4 per cent of cottonseed meal was fed to Lot 4 in Experiment 7 and 22 per cent to Lot 3 for the first 16 weeks in Experiment 8, the two rations contained approximately 0.015 and 0.018 per cent of gossypol, respectively.

The North Carolina results have indicated that the level of toxicity of gossypol for rats is 0.08 to 0.1 per cent. Clark's work (10) showed that 0.05 per cent of gossypol in the ration noticeably retarded growth, that 0.1 per cent depressed growth to a still greater extent, and that 0.125 per cent was definitely toxic to rats. Inasmuch as the above rations proved toxic for pigs, even the smaller amount used in the first trial causing death losses, the data indicate that gossypol is from 5.3 to 6.6 times as toxic to pigs as to rats. This agrees with the conclusions drawn from the earlier experiments, reported on page 7, as to the relative susceptibility of pigs and rats to cottonseed or cottonseed meal injury.

EXPERIMENT 9

During the winter of 1915-1916, or subsequent to the reports of Withers and Brewster (53) and of Withers and Carruth (54) that a solution of iron was beneficial in diminishing or averting the toxic effect of cottonseed meal, two

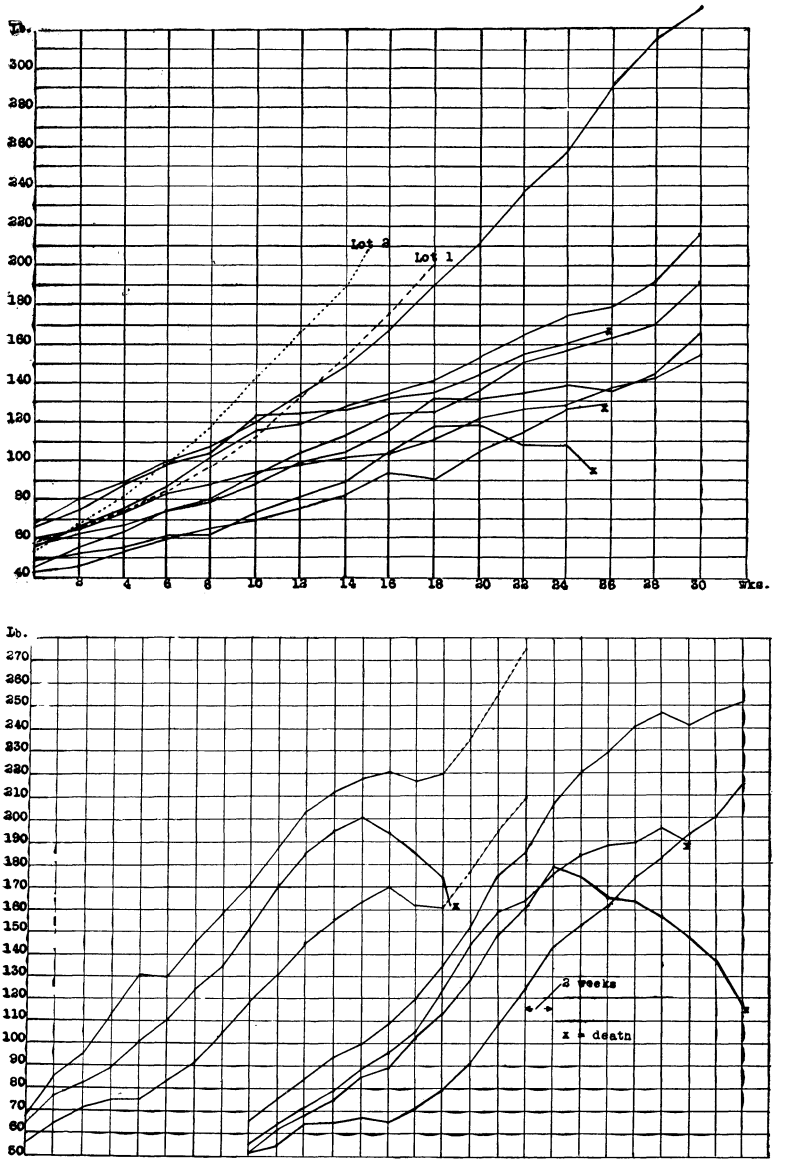

Fig. 6.—(Upper).—Individual growth curves of pigs in Lot 3, Experiment 8. Showing that vitamin A does not protect pigs against the toxicity of cottonseed meal

. . . . . Lot 1. - - - - - Lot 2. ——— Lot 3.
X=deaths.

(Lower).—Individual growth curves of pigs in Lot 1, Experiment 7
——————— Ration deficient in vitamin A.
- - - - - - - - Ration changed to supply vitamin A.

lots of five pigs each were fed cottonseed meal and a third tankage as supplements to yellow corn. Salt, ground limestone, and ground rock phosphate, in separate containers, were kept before each group of pigs. The other feeds were fed twice daily. A solution of one pound of copperas, or iron sulfate, in 50 gallons of water was prepared, and the feed for Lot 3 moistened or made into a slop with this solution shortly before feeding time. The solution was added at the rate of one gallon for each pound of cottonseed meal fed.

TABLE 8.—Experiment 9

	1 Yellow corn Tankage	2 Yellow corn Cottonseed meal, with dry iron sulfate	3 Yellow corn Cottonseed meal, with iron sulfate solution
Av. per cent of cottonseed meal	.....	**15.5**	**16.0**
No. of pigs at start	5	5	5
No. of removals	1	0	1
No. of deaths	**0**	**4**	**0**
Initial weight per pig, lb.	36.3	36.4	36.7
Final weight per pig, lb.	113.5	47.0*	104.0
Av. daily gain, lb.	**0.72**	**0.35**	**0.65**
Daily feed per pig, lb.:			
Corn	2.28	1.68	2.34
Cottonseed meal	.....	0.32	0.45
Tankage	0.31	.....	.....
Minerals	0.03	0.05	0.05
Total	**2.62**	**2.05**	**2.84**
Feed per 100 lb. gain, lb.:			
Corn	318.20	484.52	358.66
Cottonseed meal	.....	91.67	69.71
Tankage	42.59	.....	.....
Minerals	4.11	14.29	7.12
Total	**364.89**	**590.48**	**435.49**
Cost of feed per 100 lb. gain	$ 4.46	$ 5.03	$ 6.83

*Since only one pig remained, Lot 2 was discontinued at the close of the 8th week. Lots 1 and 3 were fed for a period of 14 weeks.

Minerals: Salt, limestone, and ground rock phosphate; each kept before the pigs in a separate container.

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; tankage, $2.10; minerals, $1.50; grinding corn, 10¢.

Two per cent as much dry, powdered iron sulfate as cottonseed meal was mixed with the feed for Lot 2, and the feed moistened with water just prior to feeding time. Four pigs out of five in the lot had died by the end of the 8th week. Two deaths occurred on the 41st day, one on the 51st, and one on the 53rd day of the experiment.

Lots 1 and 3 were continued for a period of 14 weeks. One pig in Lot 3 succumbed to spasms or tremors on the 28th day and was removed from the lot. None died in the 14-week period. A single experiment of rather short duration, especially with so few pigs to the lot, is not regarded as conclusive. Apparently, however, the iron sulfate solution made the cottonseed meal less toxic, but mixing the dry iron sulfate with the feed was of no benefit in overcoming the toxicity of the cottonseed meal.

EXPERIMENT 10

To secure further data on the value of an iron solution in overcoming the injurious effect of cottonseed meal, two groups of eight pigs each were fed rations made up of ground yellow corn, cottonseed meal, ground alfalfa, and minerals. The pigs were started at an average weight of approximately 75 pounds, and the cottonseed meal was reduced from 17 to 12 per cent of the total feed when they averaged approximately 125 pounds in weight. Four per cent of alfalfa and 2.5 per cent of minerals were included in each ration. Five per cent of the mineral mixture for Lot 1 was made up of copperas ($FeSO_4 \cdot 7H_2O$), or iron sulfate. This, together with that in the feed, was intended to furnish an abundance of iron for normal metabolism but not enough to counteract the toxic effect of the cottonseed meal.

No iron was included in the mineral mixture for Lot 2, but one pound of copperas dissolved in one-half gallon of water was added to the cottonseed meal before it was mixed with the other feeds. Through a misunderstanding, the solution was added to the amount of cottonseed meal used in each 100 instead of each 500 pounds of feed, or five times as much iron as intended was fed for

TABLE 9.—Experiment 10

Started Aug. 9, 1933	1 Yellow corn **Cottonseed meal** Ground alfalfa Minerals (1)	2 Yellow corn **Cottonseed meal*** Ground alfalfa Minerals (2)	3 Yellow corn **Tankage** Ground alfalfa Minerals (1)
Av. per cent of cottonseed meal	**13.6**	**13.6**	.....
No. of pigs at start	8	8	8
No. of deaths	**0**	**0**	**0**
Initial weight per pig, lb	74.7	74.2	75.6
Final weight per pig, lb	219.4	222.7	224.0
Av. daily gain, lb	**1.15**	**1.18**	**1.33**
Days required to gain 160 lb	140	136	121
Daily feed per pig, lb.:			
Corn	4.08	3.92	4.86
Cottonseed meal	0.70	0.67	.....
Tankage	.....	.....	0.43
Ground alfalfa	0.20	0.20	0.22
Minerals	0.13	0.12	0.11
Total	**5.11**	**4.91**	**5.62**
Feed per 100 lb. gain, lb.:			
Corn	355.24	333.11	366.31
Cottonseed meal	60.65	56.66	.....
Tankage	.....	.....	32.15
Ground alfalfa	17.79	16.67	16.95
Minerals	11.12	10.42	8.48
Total	**444.80**	**416.86**	**423.89**
Cost of feed per 100 lb. gain	$ 5.07	$ 4.75	$ 5.08

Minerals (1): Salt, 19; limestone, 38; special steamed bone meal, 38; iron sulfate, 5.
Minerals (2): Salt, 20; limestone, 40; special steamed bone meal, 40.
*One pound of iron sulfate was dissolved in ½ gallon of water and this solution mixed with the cottonseed meal in each 100 pounds of feed for Lot 2.
Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; dry-rendered tankage, $2.45; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

the first 16 weeks of the trial. Although the heavy allowance of copperas imparted a black color to the droppings and possibly slightly reduced the feed consumption, apparently it was not harmful to the animals.

Gallup concluded from his studies (20) that iron delayed the effects of cottonseed meal injury by combining with the gossypol to form an insoluble compound and that a quantitative relationship existed between the amount of gossypol in the ration and the iron needed to counteract its toxic effect. Rats which he fed ferric citrate and ferrous ammonium sulfate in a finely powdered form and in quantities sufficient to furnish 3 grams of iron to each gram of gossypol made nearly normal growth.

Lot 3 was fed the same as Lot 1, except that dry-rendered tankage was substituted for the cottonseed meal.

Cottonseed meal from the same supply as that used during the early part of Experiment 8 was fed for the first 8 weeks of the test. Thereafter, meal from the same supply as that used during the latter part of Experiment 8 was fed. Three pigs in Lot 3 of Experiment 8 died in 22 to 25 days after the change in meals was made. Although it is not regarded as probable, there is a possibility that their deaths could have been caused by the after effects of the first meal. Hence, the cottonseed meal used during the greater portion of the experiment was thought, but not definitely known, to be toxic.

Neither the pigs given the dry copperas in their minerals nor those given the cottonseed meal which had been treated with the copperas solution manifested any noticeable symptoms of cottonseed meal injury.

Since less cottonseed meal, particularly after the change in feed was made, was fed than in several of the other experiments reported and since the pigs used were somewhat heavier at the start than those in the other trials, the ration may not have contained sufficient gossypol to produce any marked ill effects in the length of time the feeding was continued. Lot 2 required 6.3 per cent less feed per unit of gain than Lot 1. Conclusive proof that treating cottonseed meal with a solution of copperas overcame its toxic effect was not provided by Experiments 9 and 10. The evidence secured, however, indicated that it did and, considering the earlier experiment especially, that merely including dry copperas in the ration was less effective than treating the cottonseed meal with a solution of copperas[2].

AVERAGE RESULTS

The results of four experiments comparing the special cottonseed meal developed by the Procter and Gamble Company with regular cottonseed meal, when fed both with and without tankage, are summarized in Table 10.

Seventeen pigs out of 35 fed the regular cottonseed meal as the only protein concentrate in the ration died during the course of the experiments. Death losses occurred in each of the four experiments. Three pigs out of 35 on the special meal died. Thus, the mortality was 48.6 per cent on the regular and 8.6 per cent on the special meal. The pigs getting the special meal gained 32.8

[2]In an experiment which has now been in progress for 126 days three pigs out of eight, started at an average weight of 40 pounds and fed yellow corn, cottonseed meal, ground alfalfa, and minerals, have died, one on the 77th, one on the 105th, and one on the 109th day. The minerals consisted of salt, limestone, and bone meal. A similar ration, except that the cottonseed meal was treated with a solution of copperas, has produced faster but not normal growth and has caused no deaths or symptoms of a toxic effect. Each 100 pounds of feed contained 19.5 pounds of cottonseed meal. Approximately 1.5 pounds of copperas per 100 pounds of cottonseed meal was used and this was dissolved in 2.5 gallons of water.

per cent faster and required 11 per cent less feed per unit of gain than those on the regular meal. Based only on the smaller amount of feed required per unit of gain and with the regular meal valued at $28.00 a ton, the special meal, when fed as the only protein concentrate, showed a comparative value of $43.08 per ton, or was worth approximately 54 per cent more than the regular meal.

TABLE 10.—Summary of Comparisons of Regular and Special Cottonseed Meals

	Corn **Cottonseed meal** Alfalfa Minerals	Corn **Cottonseed meal Tankage** Alfalfa Minerals	Corn **Special cottonseed meal** Alfalfa Minerals	Corn **Special cottonseed meal Tankage** Alfalfa Minerals	Corn **Tankage Linseed meal** Alfalfa Minerals
Av. per cent of cottonseed meal	**19.3**	**8.3**	**19.0**	**8.3**	.....
No. of experiments	4	4	4	4	4
No. of pigs at start	35	35	35	35	34
No. of removals	0	1	2	2	0
No. of deaths	**17**	**0**	**3**	**0**	**0**
Initial weight per pig, lb.	49.4	49.5	49.4	49.3	49.9
Final weight per pig, lb.	197.3	199.2	203.8	204.8	207.3
Av. daily gain, lb.	**0.64**	**0.97**	**0.85**	**1.06**	**1.10**
Days required to gain 160 lb.	250	165	188	151	145
Daily feed per pig, lb.:					
Corn, yellow	2.54	3.50	3.03	3.74	3.76
Cottonseed meal	0.66	0.36	0.76	0.38	.....
Tankage	.....	0.27	.....	0.30	0.45
Linseed meal	.....	.....	.....	.....	0.14
Ground alfalfa	0.10	0.13	0.12	0.14	0.14
Minerals	0.08	0.09	0.10	0.10	0.09
Total	**3.38**	**4.35**	**4.01**	**4.66**	**4.58**
Feed per 100 lb. gain, lb.:					
Corn	396.70	361.96	354.72	353.88	340.66
Cottonseed meal	102.00	37.44	89.36	36.59	.....
Tankage	.....	28.40	.....	28.11	40.47
Linseed meal	.....	.....	.....	.....	13.02
Ground alfalfa	15.82	13.51	14.09	13.23	12.44
Minerals	12.85	9.39	11.47	9.14	8.22
Total	**527.37**	**450.70**	**469.64**	**440.95**	**414.81**
Cost of feed per 100 lb. gain	$ 6.11	$ 5.35	$ 5.29	$ 5.24	$ 5.05

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; linseed meal, $1.80; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

When tankage was included in the ration, no death losses occurred from feeding either the regular or the special cottonseed meal. The pigs getting the special meal with tankage gained 8.5 per cent faster and required 2.2 per cent less feed per unit of gain than those getting the regular meal with tankage. Based on the saving in feed per unit of gain, the special meal was worth $33.84 a ton, or 21 per cent more than the regular meal, for feeding along with tankage.

Moistening cottonseed meal, placing it in shallow trays, and autoclaving or cooking it with steam under 14 pounds pressure was tried in four experiments. In two of these the meal was cooked for a half hour. In the other two it was cooked for a full hour. A summary of the results is presented in Table 11.

TABLE 11.—Untreated and Autoclaved Cottonseed Meal for Pigs

	Autoclaved for one-half hour			Autoclaved for one hour		
	Corn Cottonseed meal Alfalfa Minerals	Corn Autoclaved cottonseed meal Alfalfa Minerals	Corn Tankage Linseed meal Alfalfa Minerals	Corn Cottonseed meal Alfalfa Minerals	Corn Autoclaved cottonseed meal Alfalfa Minerals	Corn Tankage Linseed meal Alfalfa Minerals
Av. per cent of cottonseed meal	**18.6**	**18.0**	.....	**19.8**	**20.1**	.....
No. of experiments	2	2	2	2	2	2
No. of pigs at start	17	17	16	18	18	18
No. of removals	0	1	0	0	1	0
No. of deaths	**9**	**2***	**0**	**8**	**0**	**0**
Initial weight per pig, lb.	50.1	49.8	50.8	48.5	48.5	49.1
Final weight per pig, lb.	202.6	203.5	208.0	198.0	210.4	212.3
Av. daily gain, lb.	**0.65**	**0.73**	**1.02**	**0.64**	**1.01**	**1.21**
Days required to gain 160 lb.	246	219	157	250	159	133
Daily feed per pig, lb.:						
Corn, yellow	2.55	2.86	3.62	2.56	3.47	3.97
Cottonseed meal	0.62	0.68	.....	0.68	0.94	.....
Tankage	.....	.....	0.40	.....	.....	0.50
Linseed meal	.....	.....	0.20	.....	.....	0.09
Ground alfalfa	0.10	0.11	0.13	0.10	0.14	0.15
Minerals	0.08	0.09	0.08	0.09	0.11	0.10
Total	**3.35**	**3.74**	**4.43**	**3.43**	**4.66**	**4.81**
Feed per 100 lb. gain, lb.:						
Corn	389.94	393.36	354.76	403.09	344.34	329.01
Cottonseed meal	95.32	92.64	.....	107.03	92.99	.....
Tankage	.....	.....	38.79	.....	.....	41.72
Linseed meal	.....	.....	19.39	.....	.....	7.72
Ground alfalfa	15.39	15.42	13.02	16.18	13.87	11.95
Minerals	12.48	12.46	7.96	13.20	11.17	8.45
Total	**513.13**	**513.88**	**433.92**	**539.50**	**462.37**	**398.85**
Cost of feed per 100 lb. gain	$ 5.93	$ 5.93	$ 5.21	$ 6.26	$ 5.37	$ 4.86

*Two others died during an outbreak of "flu" in the herd. Post-mortem examinations revealed hemorrhagic lesions but not the lesions characteristic of cottonseed meal poisoning.

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; linseed meal, $1.80; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

In one of the two trials in which cottonseed meal that had been autoclaved for a half hour was fed, two pigs, in a group of nine receiving the autoclaved meal, died during an outbreak of hemorrhagic septicemia of the pneumonic type. Indications were that their deaths were due to the disease rather than to cottonseed meal injury. In the other trial, one pig receiving the autoclaved cottonseed meal died after being on feed 104 days, and another pig after being on feed 181 days. Both pigs showed symptoms of cottonseed meal poisoning. Nine pigs out of the total of 17 fed the untreated meal died.

There was practically no difference in the amount of gain produced per unit of feed consumed, but the pigs getting the cottonseed meal that was autoclaved for a half hour produced 12 per cent faster gains than those getting the untreated meal. Although the toxicity of the meal was greatly reduced, the half hour period was not a sufficient length of time to make the meal entirely safe for pigs.

No deaths occurred among the pigs fed the cottonseed meal that was autoclaved for one hour; nor were there any indications of it exerting an injurious effect. Untreated meal from the same sources of supply caused the deaths of eight out of 18 pigs. Autoclaving the moistened meal for one hour apparently made it entirely safe, so far as preventing death losses was concerned.

The pigs fed the meal which had been autoclaved for one hour gained 16.5 per cent less rapidly and required 15.9 per cent more feed per unit of gain than those fed tankage or tankage and linseed meal as a protein supplement. In comparison with the pigs fed the untreated cottonseed meal, however, they grew 58 per cent more rapidly and consumed 14 per cent less feed per unit of gain produced.

The results obtained during the early part of the experiments, or previous to the time the pigs showed any pronounced injurious effect from receiving the untreated meals, agreed with the work of Gallup (18) which showed that autoclaving lowered the digestibility of cottonseed meal. During the first 8 weeks, in three of the four trials, the pigs receiving the untreated meal required less feed per unit of gain than those receiving the autoclaved meal.

TABLE 12.—Toxic Cottonseed Meal, at High and Low Levels, with Tankage

	High level	Low level
	Corn **Cottonseed meal** **Tankage** Ground alfalfa Minerals	Corn **Cottonseed meal** **Tankage** Ground alfalfa Minerals
Av. per cent of cottonseed meal	**20**	**6**
No. of experiments	3	3
No. of pigs at start	29	30
No. of removals	1	1
No. of deaths	**0**	**0**
Initial weight per pig, lb.	59.9	59.3
Final weight per pig, lb.	214.3	209.3
Av. daily gain, lb.	**1.11**	**1.09**
Days required to gain 160 lb.	144	147
Daily feed per pig, lb.:		
Corn, yellow	3.21	3.83
Cottonseed meal	0.96—	0.28
Tankage	0.38	0.31
Ground alfalfa	0.14	0.14
Minerals	0.08	0.08
Total	**4.77**	**4.64**
Feed per 100 lb. gain, lb.:		
Corn	289.36	351.38
Cottonseed meal	85.91	25.50
Tankage	34.25	28.62
Ground alfalfa	12.88	12.74
Minerals	7.14	7.12
Total	**429.54**	**425.36**
Cost of feed per 100 lb. gain	$ 5.32	$ 5.03

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

Table 12 summarizes the three experiments in which tankage was fed with both high and low levels of cottonseed meal in similar rations. There was very little difference in either the average rate of growth or the average amount of feed consumed per unit of gain. In two of the three trials, however, the pigs getting the ration containing the smaller percentage of cottonseed meal required slightly less feed per unit of gain than those getting a larger amount of cottonseed meal.

One theory for explaining the fact that toxic cottonseed meal can safely be fed at a high level with tankage, and perhaps other nitrogenous feeds as well, is that the proteins of cottonseed meal are unbalanced or incomplete and that the tankage, or other feed, overcomes or corrects this deficiency.

Unless the proteins of cottonseed meal are changed by either procedure, the favorable results of autoclaving the meal or of using an iron solution with it would indicate that something other than an inadequacy of the proteins is necessary to account for at least a major share of the injurious effect sometimes experienced when cottonseed meal is fed. If the proteins are inadequate and the inadequacy is not corrected by either procedure, it must be assumed that the meal is toxic as well and, also, that either supplementing its proteins or overcoming its toxicity is sufficient to prevent death losses.

The theory of the inadequacy of the proteins[3] is not in conformity with the investigations (6, 25, 32, 37, 38, 39, and 42) which have indicated the proteins of cottonseed or cottonseed meal to be of good quality or to have a relatively high nutritive value. Most of these investigations were carried on with rats or calves, or animals less susceptible to cottonseed meal injury than pigs.

If Clark is correct in his hypothesis (see page 4) that, when cottonseed or cottonseed meal is subjected to sufficient heat and moisture, the gossypol tends to combine with free amino groups of the protein molecule to form an insoluble or inert material, another possible theory is that the harmful effect of cottonseed meal is averted, when tankage or similar feeds are fed, by the gossypol combining with the proteins of the tankage in the digestive tract of the animal to form an insoluble or harmless material. When cottonseed meal is used in the amounts required to balance corn or similar feeds, probably only a part of the gossypol present would need to be changed into an insoluble or only slowly soluble form so that the quantity in the ration remaining active would be too low to prove injurious. This theory comes more nearly harmonizing the various findings with regard to cottonseed and cottonseed meal feeding than those previously advanced.

Although, based on the assumption that cottonseed meal proteins are sufficiently adequate to give reasonably satisfactory results if the toxicity of the meal is removed, such a tentative hypothesis does not preclude the possibility of some of the proteins of tankage or other feeds of similar character nicking with those of cottonseed meal in such a way as to increase the effective-

[3]In an incompleted test 40 pound pigs fed yellow corn, copperas-treated cottonseed meal, ground alfalfa, and minerals have gained only 52 per cent as rapidly and have required 34 per cent more feed per unit of gain than similar pigs fed corn, tankage, linseed meal, alfalfa, and minerals. Unless the iron treatment left enough of the gossypol active to retard growth but not enough to cause deaths, the results support the theory that cottonseed meal is not entirely adequate from the standpoint of the quality of its proteins.

ness of the supplement somewhat and thus stimulate growth and lower the feed consumption per unit of gain. Neither tankage nor linseed meal is regarded as inadequate insofar as their proteins are concerned, and yet a supplement containing both has been found superior to one containing either alone.

Table 13 gives a summary of the three experiments in which cottonseed meal was fed with tankage in a ½:1 ratio or was substituted for linseed meal in the trio supplemental mixture. The pigs receiving cottonseed meal and tankage gained 95.2 per cent as rapidly as, and required 3.3 per cent more feed per unit of gain, on the average, than those receiving the linseed meal and tankage.

TABLE 13.—Cottonseed Meal as a Substitute for Linseed Meal in the Trio Mixture

	Corn Tankage Linseed meal Ground alfalfa	Corn Tankage Cottonseed meal Ground alfalfa	Corn Tankage Linseed meal Ground alfalfa	Corn Tankage Cottonseed meal Ground alfalfa
Experiment Stations	Ohio		Six, including Ohio	
Av. per cent of cottonseed meal		**3.6**		**3.8**
No. of experiments	3	3	11	11
No. of pigs at start	28	28	108	109
No. of removals	2	2	2	3
No. of deaths	**0**	**0**	**0**	**0**
Initial weight per pig, lb.	52.8	52.3	61.5	61.4
Final weight per pig, lb.	221.9	219.5	216.3	212.2
Av. daily gain, lb.	**1.24**	1.18	**1.43**	**1.37**
Days required to gain 160 lb.	129	136	112	117
Daily feed per pig, lb.:				
Corn, yellow	4.10	4.06	4.85	4.68
Tankage	0.37	0.35	0.44	0.43
Cottonseed meal		0.17		0.21
Linseed meal	0.18		0.22	
Ground alfalfa	0.16	0.15	0.21	0.21
Minerals	0.06	0.06	0.03	0.02
Total	**4.86**	**4.79**	**5.75**	**5.55**
Feed per 100 lb. gain, lb.:				
Corn	330.07	342.90	338.90	341.12
Tankage	29.70	29.51	31.11	30.93
Cottonseed meal		14.75		15.46
Linseed meal	14.85		15.55	
Ground alfalfa	12.55	12.72	14.95	15.20
Minerals	4.72	4.90	1.74	1.68
Total	**391.89**	**404.78**	**402.25**	**404.39**
Cost of feed per 100 lb. gain	$ 4.69	$ 4.77	$ 4.81	$ 4.77

Shelled corn, 56¢ a bu.; cottonseed meal, $1.40 a 100 lb.; linseed meal, $1.80; tankage, $2.10; ground alfalfa, 80¢; minerals, $1.50; grinding corn, 10¢.

Substituting cottonseed meal for linseed meal in the trio supplemental mixture of tankage, linseed meal, and alfalfa was also tried in one or more experiments at the Iowa (13, 14), Illinois (7), Nebraska (30), Kansas (1, 3), and Minnesota (15) Stations. A summary of these and the Ohio tests, includ-

ing a total of 11 comparisons, shows that the pigs receiving linseed meal and those receiving cottonseed meal made average gains of 1.43 and 1.37 pounds daily a head and consumed 402 and 404 pounds of feed per 100 pounds of gain produced, respectively. The cottonseed meal thus made a favorable showing, and, when fed in this manner, was practically as effective as linseed meal.

In nine trials carried on by the Indiana (50), Kansas (2, 4), Nebraska (31), and Ohio Stations a mixture of equal parts of cottonseed meal and tankage was compared with tankage alone as a supplement to corn for pigs on pasture. The pigs on the two rations gained 1.44 and 1.43 pounds daily a head, respectively. An average of 359 pounds of feed per 100 pounds of gain produced was required by the pigs on each ration. Mixtures of linseed meal and tankage were likewise similar in efficiency but were not superior to tankage alone as a supplement to corn for pigs on forage.

SUMMARY

Tests in which crushed, raw cottonseed, from the same source of supply, as well as other tests in which cottonseed meal was fed to both pigs and rats, indicated that pigs were much more susceptible to cottonseed meal injury than rats. Pigs were estimated to be from five to seven times more susceptible than rats.

Neither the addition of minerals nor a combination of minerals and ground alfalfa overcame the toxic effect of a ration of yellow corn and cottonseed meal. In each of six lots in four experiments, three or more deaths occurred among the pigs fed yellow corn, cottonseed meal, and minerals, or the same feeds plus ground alfalfa. Twenty-nine pigs out of a total of 53 on such rations died. The mortality was thus 55 per cent.

The inclusion of iron sulfate, iron citrate, iron oxide, or a combination of iron oxide and copper sulfate (14:1) in the mineral mixture was not instrumental in overcoming the harmful effect from feeding cottonseed meal.

Since, in other experiments, ground alfalfa and minerals were effective in correcting the deficiencies of similar rations composed of yellow corn and linseed meal, or yellow corn and soybean oilmeal, presumably the deaths of the pigs receiving cottonseed meal were not due to a mineral or vitamin deficiency of the ration.

A group of pigs fed a vitamin-A deficient ration made up of white corn, cottonseed meal, tankage, cottonseed oil containing a vitamin-D concentrate, and minerals began showing the effects of a lack of vitamin A after having been on feed from 24 to 31 weeks. The symptoms were somewhat similar to those described as sometimes occurring in calves fed heavy allowances of cottonseed meal but were distinctly different from those of cottonseed meal injury in pigs, as observed in the experiments reported or as described by other investigators. The symptoms of vitamin-A deficiency disappeared and normal growth took place when yellow corn was substituted for the white corn and cod-liver oil was fed in place of the cottonseed oil and vitamin-D concentrate.

A ration of yellow corn, cottonseed meal, ground alfalfa, minerals, and cod-liver oil, which carried an abundance of vitamin A, produced the characteristic injury from cottonseed meal feeding and caused the deaths of three pigs out of eight. Conclusive evidence that something other than a deficiency of vitamin A is involved in cottonseed meal injury in pigs was thus provided.

Cottonseed meal made by a special process or procedure developed by the Procter and Gamble Company showed a very low toxicity as compared with that of meal made by the usual process. The regular and special meals were fed with yellow corn, ground alfalfa, and minerals in four trials and, also, with merely yellow corn and minerals in one of the four trials. A mortality of 24 out of 45 pigs, or of 53.3 per cent, on the regular, and of three out of 45 pigs, or of 6.7 per cent, on the special meal was sustained.

Moistening and autoclaving cottonseed meal under 14 pounds pressure for one hour destroyed or reduced its toxicity to such an extent that no mortalities occurred in two trials among 18 pigs that were fed yellow corn, cottonseed meal, ground alfalfa, and minerals. Untreated cottonseed meal from the same sources of supply, fed in similar rations, caused the deaths of eight out of 18 pigs.

Moistening and autoclaving cottonseed meal for one-half hour at 14 pounds pressure reduced the mortality from nine out of 17 to two out of 17, or from 53 to 12 per cent. Evidently a half hour was not a sufficient length of time to make the meal entirely safe for feeding.

The benefit of autoclaving cottonseed meal was apparently partially offset by the process bringing about a reduction in the digestibility of the meal.

During the 12-week period of an early test, no deaths occurred among five pigs which were fed a fiftieth of a pound of copperas (iron sulfate) in solution to each pound of cottonseed meal. The ration consisted of yellow corn, minerals, and 16 per cent of cottonseed meal. Four out of five pigs on a similar ration, except that dry iron sulfate instead of the solution was added to the feed, were dead by the end of the 8th week.

In a later trial, with heavier pigs and a ration containing ground alfalfa and minerals, an iron sulfate solution was mixed with the cottonseed meal for one group of pigs, and iron sulfate was used dry, at the rate of 5 per cent of the minerals, or 0.125 per cent of the total feed, for another group without any injurious effects. Since the pigs were heavier at the start and since the percentage of cottonseed meal was less, particularly after the pigs averaged 125 pounds in weight, than that used in several of the other experiments, there is a possibility that the ration failed to contain sufficient gossypol to have produced any marked, injurious effect in the length of time the feeding was continued, even if it had contained no copperas.

Cottonseed meal, which proved toxic when fed as the only protein concentrate at levels ranging from an average of 18 to 22 per cent of the total feed, caused no deaths when fed at levels not exceeding 10.5 per cent, in rations containing some tankage.

Even when cottonseed meal which caused fatalities, at the same or a slightly lower level, was fed at a high, or 20 per cent, level and tankage was included in the ration, no death losses occurred.

Although soybean oilmeal was not fed with a high level of cottonseed meal, the excellent results obtained when each averaged 8 per cent of the total feed indicated that other protein concentrates may serve in the same way as tankage to prevent losses and improve a ration containing cottonseed meal.

A theory which has been offered to explain the beneficial effect of feeding casein, tankage, or other protein concentrates with cottonseed meal is that the proteins of the cottonseed meal are inadequate or incomplete and that the added supplement helps to correct the deficiency.

The favorable results of autoclaving or of using an iron solution with cottonseed meal would indicate that, unless the proteins of the meal are changed by either procedure, something other than an inadequacy of the proteins is necessary to account for a major share of the injurious effect sometimes experienced when cottonseed meal is fed.

Furthermore, the theory of the inadequacy of the proteins is in direct conflict with the findings of those investigators who have indicated that the proteins of cottonseed or of the meal made from it are of good quality or have a nutritive value comparing favorably with that of linseed meal.

A tentative hypothesis, which comes more nearly fitting and harmonizing the various findings, is that the harmful effect of feeding cottonseed meal to pigs is averted, when tankage, or a similar protein concentrate, is fed, because the gossypol of the meal combines with the proteins of the tankage, or similar feed, in the digestive tract of the animal to form an insoluble and therefore harmless material.

Although based on the assumption that cottonseed meal proteins are sufficiently adequate to give fair results if the toxicity of the meal is removed, such an hypothesis does not preclude the possibility of some of the proteins of tankage, or other feeds, nicking with those of cottonseed meal in such a way as to increase the effectiveness of the supplement somewhat and thus to stimulate growth and lower the feed consumption per unit of gain. Neither tankage nor linseed meal is regarded as inadequate, insofar as their proteins are concerned, and yet a supplement containing both has been found superior to one containing either alone.

In practice, less cottonseed meal would be fed whenever tankage or some other protein concentrate was included in the ration, and the smaller amount fed would serve as an additional factor of safety.

From the standpoint of safety, if a maximum amount of untreated meal were to be used in the supplemental mixture for animals as susceptible to its toxic effect as pigs, a cottonseed meal containing 43 per cent of protein would be preferable to a lower grade which would need to be fed in larger quantities in order to supply an equivalent amount of protein.

Since pasture reduces the amount of protein supplement needed and since the proteins and iron supplied by it would probably tend to overcome the toxicity of the meal, pigs receiving untreated cottonseed meal as the only or chief supplement should be kept on good forage as much of the time as possible.

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